Sodium Silicate

Crops

Identification of Petitioned Substance

Chemical Names:
Sodium Silicate

Other Name:
Sodium metasilicate; Sodium silicate glass; Sodium water glass; Silicic acid, sodium salt; tetrasodium orthosilicate (IPCS, 2004)

Trade Names:
Waterglass, Britesil, Sikalon, Silican, Carsil, Dryseq, Sodium siloconate, Star, Soluble glass, Sodium polysilicate (NLM, 2011a), N® - PQ Corporation (OMRI, 2011)

CAS Numbers:
1344-09-8

Other Codes:
EPA PC code: 072603 (NLM, 2011a); European Inventory of Existing Commercial Chemical Substances (EINECS) Number: 215-687-4 (IPCS, 2004)

Characterization of Petitioned Substance

<u>**Composition of the Substance**</u>:
The basic formula of sodium silicate is $Na_2O \cdot nO_2Si$, which represents the components of silicon dioxide (SiO_2) and sodium oxide (Na_2O) and the varying ratios of the two in the various formulations. This ratio is commonly called the molar ratio (MR), which can range from 0.5 to 4.0 for sodium silicates and varies depending on the composition of the specific sodium silicate. The structural formulas of these silicates are also variable and can be complex, depending on the formulation, but generally do not have distinct molecular structures (IPCS, 2004). The basic structure of soluble silicates, including sodium and potassium silicates, is a trigonal planar arrangement of oxygen atoms around a central silicon atom, as depicted in Figure 1 below. Physical and chemical properties of sodium silicate are summarized in Table 1, on page 2.

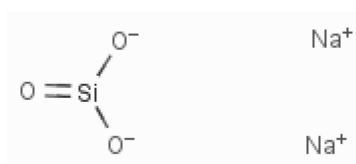

Figure 1: Chemical Structure of Sodium Silicate (NLM, 2011a)

<u>**Specific Uses of the Substance**</u>:

Sodium silicate and other soluble silicates have been used in many industries since the early 19th century. The compounds were used in the textile industry in fiber processing, and as a fire preventative on theater curtains (Wills, 1982). Sodium silicate has also been used in laundry soap, and as an adhesive for paper products (Wills, 1982). A specific formulation of sodium silicate, or "waterglass" was used in the preservation of eggs (Wills, 1982). The compound has also been used as corrosion preventer in canned drinking water and in the nuclear power industry (Geier and Clinton, 1962; EPA, 2007).

Sodium silicate may be used in organic crop production is as a floatation agent for postharvest handling of tree fruit and fiber. The primary organic handling use of sodium silicate is for floatation of fruit, especially pears. Sodium silicate is added to fruit processing water to increase the density of the water, which allows the pears to float (Willett et al., 1989). Pear floatation is used to prevent damage to the fruit during processing, and to allow the fruit to move more easily and efficiently through the packing process (Agar and Mitcham, 2000).

Specific information on the use of sodium silicate in organic postharvest handling of fiber has not been identified. However, uses of sodium silicate in the broader fiber and textile industries have been identified. For example, sodium silicate is used for processing fibers such as cotton and jute as a buffer for peroxide bleaching and as a detergent for cleaning and processing the fibers. Sodium silicate is mentioned specifically as an agent for degumming of jute fibers (Wang, et al., 2008). The use of sodium silicate as a buffer also prevents fiber damage from sodium hydroxide and may prolong the bleaching action of hydrogen peroxide by preventing catalysis (Lewin, 1984). Sodium silicate may be used as an additive for bleaching in combination with other processing compounds including: water, various enzymes, citric or acetic acid, and hydrogen peroxide (Green Textile Associates, 2007). Another use of sodium silicate is as a flocculant aid in fiber processing to decrease the turbidity of raw process water (PQ Corporation, 2003). No additional information was found on flotation uses for sodium silicate in fiber processing.

Table 1. Chemical Properties of Sodium Silicate:

Chemical or Physical Property	Value
Color	Colorless or white to grayish-white; also greenish glass or clear to cloudy liquid (Budavari, 1989; Sax and Lewis, 1987).
Physical State	Lumps, powders, or crystal-like or glass-like pieces. Also a cloudy or clear liquid (Budavari, 1989; Sax et al., 1987).
Odor	Odorless (CAMEO Database of Hazardous Materials, 1999)
Melting Point	Amorphous silicates such as sodium silicate do not have melting points, but rather flow points due to their glass state. Sodium silicate reaches flow point at 730 to 870 °C, and starts to soften at 550 to 670 °C, depending on the compound's molar ratio. Aqueous solutions of silicates have a melting point that is slightly higher than water (IPCS, 2004).
Boiling Point	Boiling point not applicable for solid, anhydrous silicates, because they are glasses. Boiling point of aqueous silicate solutions is dependent on the water present and will be similar to the boiling point of water (IPCS, 2004).
Solubility	Heating with water under pressure brings chemical into solution, which is then infinitely dilutable with water (IPCS, 2004). Slightly to almost insoluble in cold water (Budavari, 1989). Partially miscible with ketones and primary alcohols (Sax and Lewis, 1987). Amorphous silica obtained by precipitation from the neutralization of alkaline sodium silica solutions is soluble in water at 115 mg/l at 25 °C (IPCS, 2004).
Stability	Aqueous sodium silicate solutions have a pH-dependent polymerization/hydrolysis equilibrium of oligomeric silicate ions, monomeric aqueous silicon dioxide, and polysilicate ions (IPCS, 2004).
Reactivity	Sodium silicate used in pear flotation may gel at low pH values or when combined with acidic solutions such as lignin sulfonates (Willett, et al., 1989). Aqueous solutions of sodium silicate react as bases (CAMEO Database of Hazardous Materials, 1999). Sodium silicate reacts violently with fluorine (CAMEO Database of Hazardous Materials, 1999).
Oxidizing or Reduction Action	Some sodium silicate species are oxidizers and may ignite combustible items such as paper, wood, oil, or clothing (U.S. DOT, 2008).
Flammability	Noncumbustible (Sax and Lewis, 1987). May decompose when heated to produce toxic or corrosive fumes (U.S. DOT, 2008).
Explodability	Soluble silicates are not explosive (IPCS, 2004).

Approved Legal Uses of the Substance:

Sodium silicate is included on the National List of Allowed and Prohibited Substances (hereafter referred to as the National List) as a synthetic substance allowed for use in organic production (7 CFR 205.601). Sodium silicate may be used in organic crop production as a floating agent in postharvest handling for tree fruit and for fiber processing only (see 7 CFR 205.601(l)(2)).

Sodium silicate has been characterized as Generally-Recognized as Safe (GRAS) by the U.S. Food and Drug Administration (FDA) in 21 CFR 182.90 and 21 CFR 182.1711. The regulation is based on sodium silicate use on a limited basis in canned potable water as a corrosion inhibiting agent (EPA, 2007).

Sodium silicate is exempt from the requirement of a tolerance when it is used as an inert ingredient in pre- and post-harvest agricultural products (see 40 CFR 180.910). Tolerances are acceptable levels of pesticide residues on food products that are set by the U.S. Environmental Protection Agency (EPA), and enforced by the USDA and FDA. According to 40 CFR 180.900, "An exemption from a tolerance shall be granted when it appears that the total quantity of the pesticide chemical in or on all raw agricultural commodities for which it is useful under conditions of use currently prevailing or proposed will involve no hazard to the public health" (EPA, 2007)

Action of the Substance:

Sodium silicate dissolves in water when heated under pressure to form an aqueous solution. The resulting solution is dilutable with water to a wide range of densities, depending on the relative amounts of sodium silicate and water that are used (IPCS, 2004). When the sodium silicate solution (or salts of soluble sodium silicate) is added to dump water in the processing of pears or other tree fruit, it increases the density of the dump water, which allows the fruit to float (Agar and Mitcham, 2000). When sodium silicate is used in fiber processing, it is added to peroxide bleaching solutions as a buffer for the acidic peroxide. The buffering action also acts to prevent fiber damage that could result from over-bleaching, and stabilizes the peroxide from catalysis by other compounds in the solutions (Lewin, 1984). The detergent properties of sodium silicate are used in jute processing for degumming of the jute fibers (Wang et al., 2008). Sodium silicates are also used in combination with iron salts, alum, or other coagulants as a flocculant in fiber processing to decrease turbidity in raw fiber process water (PQ Corporation, 2003).

Combinations of the Substance:

No information was found on the intentional use of sodium silicate as a precursor to, component of, or as an addition to substances identified on the National List. As mentioned in Table 1, sodium silicate used in pear flotation may gel at low pH values. This reaction could cause the flotation solution to become too thick for its intended use. Acidic conditions could occur from using a mixture of flotation salts, such as combination of sodium silicate with an acidic solution containing lignin sulfonates (Willett, et al., 1989). For this reason, sodium silicates are not typically used in combination with lignin sulfonates, but some operators may not be aware of this reactivity.

Status

Historic Use:
Soluble silicates, including sodium silicate, have a history of use dating to the early 19th century. The compounds have been used in the production of textiles and as a treatment for fire prevention on theater curtains. A major early application of soluble silicates was in laundry soap. Soluble silicates were also used as an adhesive for paper shipping containers, but the use was replaced by starch-based adhesives (Wills, 1982).

Sodium silicate, referred to as "waterglass," was used in the home preservation of eggs from the late 1890s to mid-1930s. The diluted waterglass was added to ceramic crocks containing the eggs, which were kept in cellars. The waterglass prevented bacterial infection, preserved the water content of the eggs, and prevented loss of the air cell in the eggs. Eggs were stored in this way for up to 9 months at a time (Wills, 1982).

Sodium silicate was evaluated for use as a process water additive to inhibit corrosion at the Hanford nuclear facility in Richland, WA. The addition of sodium silicate in place of the previously used sodium dichromate was found to reduce the concentration of significant radioisotopes in the effluent by a factor of two (Geier and Clinton, 1962). Sodium silicate has also been used as a corrosion preventer in canned potable water (EPA, 2007).

OFPA, USDA Final Rule:
The petitioned substance is explicitly listed in the National List of Allowed and Prohibited Substances in 7 CFR section 205:

- 205.601(l) – As floating agents in postharvest handling (2) Sodium silicate for tree fruit and fiber processing.

International
The Canadian General Standards Board allows the use of sodium silicate for tree fruit and fiber processing (Canadian General Standards Board, 2009). Sodium silicate is included by the CODEX Alimentarius Commission as a Permitted Substance for the Production of Organic Foods. Sodium silicate is further classified as a mineral substance for plant pest and disease control. No further stipulations on its use are mentioned (Codex Alimentarius Commission, 2010). Sodium silicate is included in the group "Silicates" in the IFOAM Basic Standards for Organic Production and Processing, Version 2005. The group "Silicates" is listed under substances of Mineral Origin in the Crop Protectants and Growth Regulators section, with no additional conditions for use (IFOAM, 2005). Sodium silicate is not listed for use with crops in the European Economic Community (EEC) Council Regulations, EC No. 834/2007 and 889/2008. The Japan Agricultural Standard (JAS) for Organic Production permits the use of sodium silicate for manufacturing, packaging, storage, processing, other processes in the case that "…ordinary means are not effective enough." Sodium silicate can be used in the organic production "…except for the purpose of pest control for plants" (MAFF, 2006).

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

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

(A). Sodium silicate is not included in any of the categories listed.

(B). Sodium silicate is a synthetic inert ingredient that is listed in EPA List 4B. This compound is exempt from the requirement for a tolerance under 40 CFR part 180.1001(c).

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

Solid glass is usually produced in a rotary kiln or tank furnace by fusing quartz sand with potash or soda at temperatures ranging from 1,100 to 1,300 °C. Sodium silicate, which represents the majority of soluble silicates produced, is converted from solid glass to liquid solution at 100 °C (at standard pressure) or at 150

°C in an autoclave at increased pressure. The sodium silicate can be concentrated or diluted with water, and adjusted with the addition of alkali hydroxide according to the needs of the specific application (IPCS, 2004). Sodium silicate can also be generated from a hydrothermal production process in which silicate solutions are obtained by fusing sand and potassium or sodium hydroxide under 20 bar pressure in an autoclave heated to 200 °C (IPCS, 2004).

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

As discussed in Evaluation Question #2, the production processes for lump glass (a type of glass formed from breaking larger pieces) and sodium silicate both require high temperatures and sometimes high pressures to convert quartz sand (silicon dioxide) and soda or potash to soluble silicates (IPCS, 2004; Cummings, 2001). These processes are industrial in nature, and do not occur naturally (IPCS, 2004). Thus, sodium silicate is a synthetic substance.

Silicon dioxide, the precursor compound for the manufacture of glass and soluble silicates, is naturally occurring and makes up 59% of the elemental composition of the earth's crust. Silicon dioxide is found at similar rates in soil and sediment as in the earth's crust, and is found in all natural waters. Various organisms, including diatoms, protozoans, sponges and other plants and animals, can take up soluble silica from the environment and incorporate it into their shells and skeletons. Notable examples are diatoms, which form large deposits of silicon dioxide called diatomaceous earth (IPCS, 2004).

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

Silicon dioxide, the central molecule of sodium silicate, makes up more than half of the elemental composition of the earth's crust, and is found in all natural waters at an average concentration ranging between 10 and 20 mg/l (IPCS, 2004). Median values of silicon dioxide in US waters from a 1964 publication were 17 mg/l and 14 mg/l for groundwater and streams, respectively (Davis, 1964). Worldwide, the mean concentration of silicon dioxide in rivers is 13 mg/l. In lakes and seawater, the surface layers typically have low concentrations of silica, less than 1 mg/l, possibly due to the incorporation of silicon into the skeletons of diatoms. Aquatic organisms such as diatoms and lower plants such as grasses contain the highest concentrations of silicon in living organisms, though most living things contain some silicon (IPCS, 2004).

Transport and distribution of sodium silicate and other soluble silicates in the environment is dependent on pH and concentration, and is highly variable due to dynamic speciation of soluble silicates into a number of different anions and amorphous silica forms. Globally, total anthropogenic inputs of soluble silicates are very small to negligible compared to the concentrations resulting from natural silica flux.

Soluble silicates, including sodium silicate, are diluted and depolymerize rapidly in the environment, yielding molecular forms that are indistinguishable from natural dissolved silica in the earth's waters (IPCS, 2004). Sewage treatment may remove a approximately 10% of the soluble silicates at treatment plants, and another 10% may be deposited as sediment or adsorbed in the sewer system before reaching the treatment plant (van Dokkum et al., 2004 as cited in IPCS, 2004). Discharges from pulp and paper plants based on mass balances showed that 40% of the soluble silicates used were discharged from the plants. The calculated discharges into surface water were 151 kilotons and 54 kilotons of silicon dioxide per year from detergent and pulp/paper use, respectively. On a large scale (Western Europe), the discharges are a small percentage of the estimated 5 megatons total flux of SiO_2 per year that results from geochemical weathering. However, on a more local level, discharges of silicon dioxide to smaller areas of watersheds or waterways could cause increases of 10 to 40% from background levels.

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

Laboratory toxicity studies with sodium silicate are reported in the International Program on Chemical Safety (IPCS) Screening Information Data Set (SIDS) Initial Assessment Report (2004) for acute oral studies as well as skin and eye irritation. Acute oral LD_{50} values in rats of 3,400 and 5,150 mg/kg bodyweight (depending on the molar ratio [MR] of SiO_2 to Na_2O) are reported. Sodium silicate was irritating to rabbit skin at 40.9% concentration in solution at MR 2.0, and was corrosive to skin at both 82% (MR 2.4) and 53.5% (MR 1.6). The reported eye irritation studies were conducted on a non-validated test system, therefore the results are not reported here (IPCS, 2004). Corrosivity is of concern when sodium silicate is formulated as a strong alkaline solution (Holland, 2003). The no-observed adverse effect level (NOAEL) of sodium silicate in a 180-day study in rats was 159 mg/kg bodyweight per day, the highest tested dose (IPCS, 2004).

Sodium silicate tested negative for genotoxicity (toxic action or damage to the heritable chromosomes) in *in vitro* tests with *E. coli*, and no chromosomal aberrations were observed in Chinese hamster V79 cells (IPCS, 2004; ExtoxNet, 1998). A reproductive toxicity study in rats showed no dose-related effects on liter size at doses less than or equal to 159 mg/kg bodyweight per day. The total number of offspring born to mothers dosed at 79 mg/kg bw/day was reduced by 33 percent and the number of offspring weaned was reduced by 54%, compared to controls. (IPCS, 2004).

Acute toxicity studies in Zebrafish (*Danio rerio*) and Rainbow Trout (*Oncorhynchus mykiss*) showed 96-hour LC_{50}[1] values of 1,108 mg/l and 260-310 mg/l, respectively. These values correspond to the "practically nontoxic" category, according to the EPA Ecotoxicity Categories for Terrestrial and Aquatic Organisms (US EPA, 2010). A 48-hour EC_{50}[2] of 1700 mg/l was observed in the water flea (Daphnia magna), which also corresponds to the "practically nontoxic" ecotoxicity category (IPCS, 2004).

Sodium silicate is an inorganic substance. Biodegradation of sodium silicate is not applicable due to its inorganic composition (IPCS, 2004). In a biodegradation study with sewage sludge, greater than 90% of the applied sodium silicate was recovered in the sewage effluent (IPCS, 2004). Sodium silicate does not have a biological oxygen demand (BOD) in aquatic systems (IPCS, 2004). As mentioned in Evaluation Question #4, sodium silicate will degrade abiotically and depolymerize once in aquatic environments to silicon species (including SiO_2 and H_4SiO_4) which are indistinguishable from naturally-occuring silica compounds (IPCS, 2004).

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

As described in the response to Evaluation Question #5, sodium silicate is of very low toxicity to aquatic organisms (IPCS, 2004). However, sodium silicate is depolymerized to silicon dioxide and other related compounds including orthosilicic acid, which are taken up by diatoms, lower plants (including grasses) and some other plants and animals (van Dokkum et al., 2004; IPCS, 2004). The flux of dissolved silicate from anthropogenic sources in Western Europe compared to that for natural sources, such as weathering of rock and soils, is about 4% overall (van Dokkum et al., 2004).

There may be larger point contributions of dissolved silicates to aquatic environments, as has been observed for outflow locations of pulp and paper plants and water treatment plants. At these locations, the contribution of industrial sources of soluble silicates to background levels may be substantially higher than observed overall (van Dokkum et al., 2004). Increases in dissolved silicates near industrial point sources of the compounds could decrease ratios of both nitrogen and phosphorus to silicon which could, in turn, affect phytoplankton diversity and favor diatom growth over other aquatic organisms (van Dokkum et al.,

[1] The LC_{50}, or median lethal concentration, is the concentration of a substance in air or water that kills 50% of the experimental organisms in a study in a specified amount of time (Di Giulio and Newman, 2008).
[2] The EC_{50}, or median effective concentration, is the concentration of a substance affecting 50% of the experimental organisms in a study during a specified period of time, such as growth or development (Di Giulio and Newman, 2008).

2004). However, significant adverse effects on aquatic ecosystems have not been expected (van Dokkum et al., 2004).

Sodium silicate has been classified by the Commission for the Evaluation of Substances Hazardous to Water in Germany as water hazard class 1 (Umweltbundesamt, 2011). There are three water hazard classes: 1 – low hazard to waters; 2 – hazard to waters; 3 – severe hazard to waters (Umweltbundesamt, 2011).

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

Both sodium silicate and lignin sulfonate are allowed for use as floatation agents in postharvest handling of fruits. Lignin sulfonate serves the same purpose as sodium silicate, but has an acidic pH. Sodium silicate can gel at low pH, so it is recommended that sodium silicate and lignin sulfonate, or any other acidic dump tank additives not be used in the same tank to process fruit (Sugar and Spotts, 1989).

Given that the sodium silicate and lignin sulfonate are used for the same purpose, and due to the recommendation that they not be used together (Sugar and Spotts, 1989), interaction between the two would occur primarily in accidental situations. The outcome of the chemical interaction would be gelling of the floatation solution, which would cause sodium silicate and lignin sulfonate to be less effective for their intended use. Intentionally gelled sodium silicate is used for soil stabilization for foundations and containment of waste in soil matrices (Ahmad et al., 2001). The sodium silicate used for these purposes is subjected to an electric current and acidic conditions, in a process called grouting, which causes the gelling and stabilization of the soil (Ahmad et al., 2001).

No available information was found that discussed the environmental or human health effects of gelled sodium silicate alone or in combination with lignin sulfonate. No information on other chemical interactions was found.

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

Sodium silicate is unlikely to contaminate soil or adversely affect soil organisms based its normal use pattern, which is as an additive to fruit processing dump water bins, or as an additive to solutions used for processing fibers such as cotton and jute. In the case of a spill or manufacturing accident, sodium silicate could be discharged to terrestrial or aquatic environments. As discussed in Evaluation Question #6, large amounts of dissolved silicates discharged from a large spill could lead to a decrease in ratios of both nitrogen and phosphorus to silicon in aquatic systems (van Dokkum et al., 2004). Decreased relative nitrogen and phosphorus could affect phytoplankton diversity and favor diatom growth over other aquatic organisms. However, significant adverse effects on aquatic ecosystems from this scenario have not been expected (van Dokkum et al., 2004).

As discussed in Evaluation Question #7, sodium silicate may gel when it comes into contact with acidic conditions (Sugar and Spotts, 1989). It is possible that large spills of sodium silicate to acidic soils could cause the same gelling, which could adversely affect soil flora. However, the potential of this specific reaction has not been investigated in the available literature. In one study that investigated the potential of various floatation salts to prevent postharvest decay, sodium silicate was found to allow significantly more bacterial decay of fruit than all of the other salts tested (Sugar and Spotts, 1986). Based on these findings, the general impact of sodium silicates on survival of microbiological flora may be limited.

Sodium silicate may be produced in a form with a high pH, as is commonly used for fruit floatation and fiber processing (Sugar and Spotts, 1989; Lewin, 1984). One study with rice plants found that sodium silicate increased soil pH by 1 unit when added to the soil (Jianfeng and Takahashi, 1991). Rice plants in soil treated with sodium silicate also had increased shoot dry weight, increased silicon content, and a higher phosphorus to manganese ratio in the shoot. The nitrogen concentration in the shoots from soil treated with sodium silicate was nearly double that of controls. Relative manganese concentrations in the plants were significantly decreased. The authors speculated this change was caused by the increased amounts of silicon, which may have indirectly contributed to the improved phosphorus utilization in the plant (Jianfeng and Takahashi, 1991).

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

As discussed in Evaluation Questions #3 and #4, sodium silicate released to aquatic environments will depolymerize to form silicon dioxide and various other forms similar to naturally occurring silicon dioxide resulting from geological processes (IPCS, 2004). In addition, anthropogenic inputs of silicon dioxide resulting from sodium silicate use in fruit floatation are minute compared to natural fluxes of silicon dioxide (IPCS, 2004). However, as discussed in Evaluation Question #6, large amounts of sodium silicate discharged to aquatic systems (as from paper pulping operations) could affect the balance nitrogen and phosphorus, which could lead to effects in phytoplankton and diatom populations (van Dokkum et al., 2004).

Sodium silicate has a high pH in the range of 11-12 (IPCS, 2004). Large discharges of sodium silicate to soil or waterways could raise the pH of those environments. Increases in pH could affect the balance of soil microorganism populations. Sodium silicate has also been shown to increase growth and nutrient uptake of rice and cucumber when applied to the soil (Jianfeng and Takahashi, 1991; Husby, 2002). Silicon compounds have been shown to have beneficial effects on terrestrial plants, including decreased susceptibility to pathogens, increased growth, and decreasing the impact of abiotic plant stressors (Husby, 2002).

<u>Evaluation Question #10:</u> Describe and summarize any reported effects upon human health from use of the petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (i), 7 U.S.C. § 6517 (c) (2) (A) (i)) and 7 U.S.C. § 6518 (m) (4)).

Tanaka and colleagues (1982) published a report of a 57-year-old male with contact dermatitis and contact urticaria from exposure to sodium silicate. The man had experienced ulcerative lesions on his hand for two years before the report. The authors did not see a similar response in healthy subjects exposed to sodium silicate (Tanaka et al., 1982). The potential exists for workers who handle sodium silicate products for pear floatation or for fiber processing to be exposed to the compound during mixing or disposal. Workers handling sodium silicate for fiber processing may encounter strong acids such as hydrogen peroxide, which are later mixed with the sodium silicate. These acids could cause skin burns or other dermal adverse effects, due to their low pH. Worker contact with the buffered peroxide/sodium silicate solution would be less likely cause adverse effects due to the more neutral pH of the solution. Worker exposures to sodium silicate and/or other compounds would most likely occur as a result of accidents or failure to wear appropriate personal protective equipment.

The high pH of sodium silicate makes it irritating to the skin at 40% concentration and corrosive at 82% concentration (Cuthbert and Carr, 1985; Karlsson and Loden, 1984). If sodium silicate is swallowed, it can cause vomiting and diarrhea (Grant, 1986). Ingested sodium silicate is partially absorbed and excreted via the urine, and chronic oral exposures to sodium silicate may cause the buildup of urinary calculi (stones) (Gosselin et al., 1984). Sodium silicate can cause irritation to the mucous membranes and cornea of the eyes (Gosselin et al., 1984), and accidental splashes in the eyes may damage the corneal epithelium (Grant, 1986).

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

Pear Flotation: No information was available on natural substances that may be used in place of the petitioned substance for pear flotation. Information was available on allowed synthetic alternatives to the petitioned substance, as summarized below.

As discussed in the Action of the Substance section, materials used to increase the specific gravity of dump water and provide flotation for pear include lignin sulfonate, sodium sulfate and sodium carbonate (Sugar and Spotts, 1989). Lignin sulfonate is an allowed synthetic substance for organic production that can be used (with restrictions) as a floating agent in postharvest handling of fruit, among other uses (NOSB, 1995). Sodium sulfate is allowed for use in organic agriculture, but only as a livestock feed ingredient or in livestock healthcare (OMRI, 2010). Sodium carbonate is allowed for use in organic agriculture for processing non-agricultural ingredients and processing aids, as a crop fertilizer and soil amendment, and as a livestock feed ingredient (OMRI, 2010). There are no fruit processing or flotation uses described for sodium carbonate.

According to a survey from 1998 of pear packers in the western U.S., about 70 percent of packing houses used a form of lignin sulfonate for pear flotation (Sugar, 2002). However, a major source of lignin sulfonate in the Pacific Northwest closed prior to 2001, forcing growers to evaluate other alternatives for flotation (Sugar, 2002). Two new products were evaluated in 2001 by researchers at Oregon State University—K-Float (potassium carbonate) and Xeda F (potassium phosphate and potassium pyrophosphate)—along with sodium carbonate, calcium chloride, and sodium sulfate for their use in pear flotation. Of these substances, only sodium carbonate, calcium chloride, and sodium sulfate may be considered nonsynthetic. All of the products were evaluated at the Southern Oregon Research and Extension Center in Medford, OR, and the findings were reported at the Washington Tree Fruit Postharvest Conference on March 12th and 13th, 2002, in Yakima, WA. All tested products performed in a manner similar to lignin sulfonate to raise the density of water in dump tank solutions and allow pears to float for easier and less-damaging processing. In these tests, a mixture of Xeda F with Steri-Seal disinfectant at 1 percent provided the lowest gray mold infection rate (12 percent). However, all of the alternate treatments caused some degree of fruit injury at increased dump tank temperature. The exception to the rule was lignin sulfonate, which was found to lower pH levels, but also have a "safening" property for phenol injury at a low pH (Sugar, 2002).

Fiber Processing: Sodium hydroxide is also used as a buffering agent in peroxide bleaching of fibers, and has a similar mode of action and effect. The sodium hydroxide buffer is used in varying concentrations depending on the pH of the bleaching solution and the desired pH of the resultant solution (Lewin, 1984). Sodium hydroxide considered a synthetic material, allowed for use in processing non-agricultural ingredients and as a processing aid (OMRI, 2010).

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

Pear damage can occur throughout the harvest process, but one of the main sources of damage is when the pears are dumped from bins during rapid unloading. Dry dumps from harvest bins to packing bins can cause the most damage, whereas wet dumps (from a dry bin into a water-filled bin) decrease the potential for fruit injury. Wet dumps also allow pears to more easily move onto conveyors where they are inspected and packed. Due to the high density of pears, some are heavier than water. Flotation salts, including sodium silicate, are sometimes added to increase dump water density and allow the pears to float, thus reducing the chance for injury and increasing packing efficiency—a process called an immersion dump. The fruit is then circulated in the dump water using a pump, which floats the fruit to an elevator where it is rinsed and moved to a conveyor for packaging. The flotation salts could be left out of the process and non-immersion water dumps could be used. To minimize damage in non-immersion dumps from fruit-to-fruit injury, more time is required to allow fruit to move onto conveyors before additional fruit is dumped.

Additional steps to reduce fruit damage have also been proposed which include using padded picking containers or plastic-lined wooden picking bins to reduce scuffing (Agar and Mitcham, 2000).

Sodium silicate is used to buffer peroxide bleach solutions during fiber processing, and as a detergent in degumming fibers (Lewin, 1984; Wang et al., 2008). Alternative bleaching techniques employing other oxidizers besides hydrogen peroxide could be employed. However, sodium silicate or another buffer may still be required to buffer the bleaching solution, as most bleaching agents are either acidic or chlorine-based. An alternative practice of using unbleached fibers in textiles could be employed, thus eliminating the need for bleaching as well as buffering agents.

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