Fluorosilicic Acid

H_2SiF_6 (liquid)

Direct Use Chemical

Inputs to Manufacturing Process:
Phosphate Rock
Sulfuric Acid

% of Total Domestic Consumption Attributed to Water Sector:
Approximately 63%

Product Family: Phosphate

CAS No.: 16961-83-4

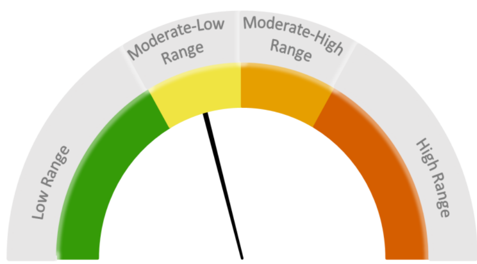
Derivative Water Treatment Chemicals: None

[Understanding Chemical Supply Chains]
[Map of Suppliers & Manufacturers]

Shelf Life: 1 Month

RISK OF SUPPLY DISRUPTION (Assessed in 2022)

RISK RATING: Moderate-Low



RISK DRIVERS

Production of fluorosilicic acid depends on the production of phosphate rock and manufacturing of sulfuric acid. Planned facility downtime at the limited number of domestic manufacturing facilities has resulted in recurring volatility in the supply of fluorosilicic acid.

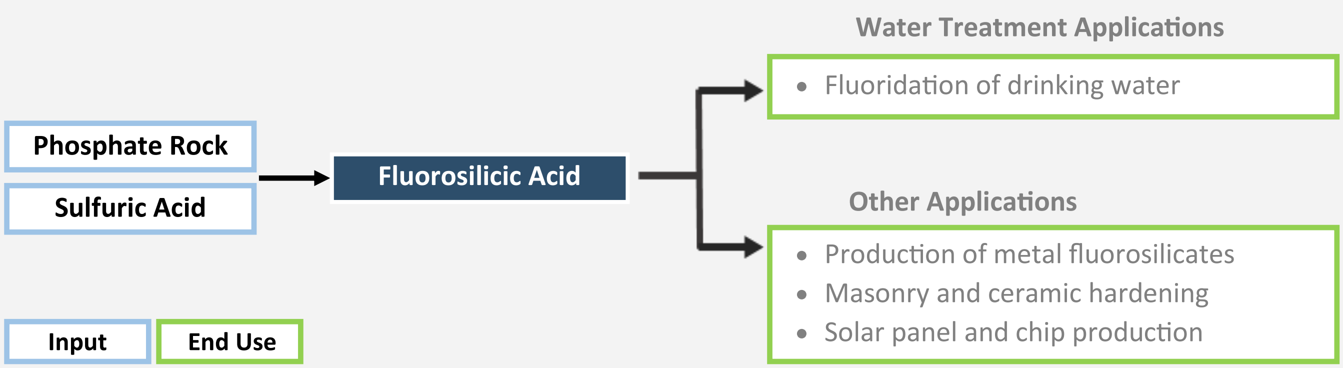
RISK PARAMETERS

Criticality: Low. Used widely but in discretionary application.

Likelihood: High. Previous widespread disruptions in supply that impacted the water sector.

Vulnerability: Moderate-High. Limited domestic manufacturing concentrated in select geographic areas and strong reliance on imports.

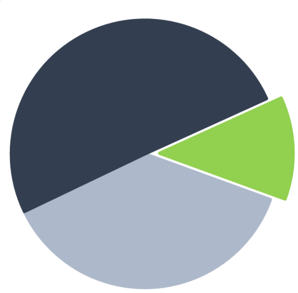
MANUFACTURING PROCESS



DOMESTIC PRODUCTION AND CONSUMPTION, AND INTERNATIONAL TRADE

Domestic Manufacturing Locations (2017):
5, in Florida, North Carolina, Louisiana, and Wyoming

International Trade (2019)
Primary Trading Partner (Imports): China
Primary Trading Partner (Exports): China



Domestic Consumption (2019): 58 M kg

- Domestic Production (29 M kg)
- Imports for Consumption (39 M kg)
- Export of Domestic Production (10 M kg)

Product Description

Fluorosilicic acid (FSA) (H_2SiF_6), a halogenated inorganic acid, is the water fluoridation compound most widely used in community water systems in the U.S. as it yields free fluoride rapidly when mixed with water. The majority of FSA produced is used for municipal water fluoridation, and the remainder is mostly consumed by the aluminum industry to produce aluminum fluoride.

Use in Water Treatment

FSA is used in water treatment for drinking water fluoridation (AWWA, 2011).

Use as a Precursor to Other Water Treatment Chemicals

None.

Other Applications

FSA is used in aluminum fluoride and other metal fluorosilicate manufacturing, hardening masonry and ceramics, metal surface treatment, and solar panel and silicon chip production. It is also used in hydrofluoric acid production (ATSDR, 2003; USGS, 2020a).

Primary Industrial Consumers

Water fluoridation is the primary use of FSA. In 2001, it is estimated that approximately 63% of FSA was consumed for water fluoridation (ATSDR, 2003).

Manufacturing, Transport, & Storage

Manufacturing Process

Production of FSA for water fluoridation takes place as a byproduct of the reaction to produce wet-process phosphoric acid. The majority of phosphate rock, represented in Figure 1 as fluorapatite ($Ca_5(PO_4)_3F$), contains approximately 3-4% fluoride. The primary reaction, which involves digestion of phosphate rock with sulfuric acid to produce phosphoric acid, is shown in Figure 1. During this reaction, sulfuric acid reacts with other elements in phosphate rock and through these reactions fluoride and silicon are mobilized to form silicon tetrafluoride and hydrogen fluoride, as shown in the secondary reaction in Figure 1. The hydrogen fluoride and silicon tetrafluoride vapors can be recovered through filtration and evaporation. When the gases are scrubbed with water, FSA is formed as a waste stream (Solvay, 2013). FSA is not a discrete compound, but rather an aqueous mixture of fluorosilicated compounds (AWWA, 2011).

Primary Reaction

Phosphate Rock + Sulfuric Acid → Phosphoric Acid + Gypsum + Hydrogen Fluoride

$$Ca_5(PO_4)_3F + 5H_2SO_4 \rightarrow 3H_3PO_4 + 5CaSO_4 + HF$$

Secondary Reaction (Gas Capture)

Silicon Tetrafluoride + Hydrogen Fluoride → Fluorosilicic Acid

$$SiF_4 + 2HF \rightarrow H_2SiF_6$$

Figure 1. Chemical Equation for the Reaction to Manufacture Fluorosilicic Acid

Product Transport

FSA is considered a strong, corrosive acid, but is commonly transported by rail and tanker truck (OxyChem, 2018). Given the limited number of domestic production facilities which are concentrated in Florida, Louisiana, North Carolina and Wyoming, long-distance transport may be required to deliver FSA throughout the U.S.

Storage and Shelf Life

FSA should be stored in cool, well-ventilated areas and under these conditions has a shelf life of one month. It is highly corrosive, and exposure to strong oxidizers or elevated temperatures can lead to the release of hydrogen fluoride and hydrogen gas through decomposition (Simplot, 2021; Solvay, 2013).

Domestic Production & Consumption

Domestic Production

Production data was collected from the U.S. Geological Survey (USGS), while trade data was collected from the U.S. International Trade Commission (USITC) Dataweb, as shown in Table 1. While production data is specific to fluorosilicic acid, trade data represents import and export of inorganic acids, 'not elsewhere specified' (NES).

Table 1. FSA Production and Trade Data Sources

Production and Trade Data			
Category	**Data Source**	**Identifier**	**Description**
Domestic Production	U.S. Geological Survey	2019 Fluorspar Data Sheet[1] CAS No.: 16961-83-4	Fluorosilicic Acid
Imports and Exports	International Trade Statistics U.S. International Trade Commission	HS Code: 2811.19 HTS Code: 2811.19.60	Inorganic Acids Other than Hydrogen Fluoride Inorganic acids, NES

Total U.S. domestic production of FSA from phosphate rock was approximately 29 million kilograms (M kg) in 2019 (USGS, 2021). The vast majority of domestic commercial manufacture of FSA is integrated with manufacturing of phosphoric acid from phosphate rock (USGS, 2020a). Domestic commercial manufacturing of FSA as a co-product of phosphoric acid production has historically taken place in Florida, Louisiana, North Carolina, and Wyoming by *J.R. Simplot, Mosaic Company,* and *PCS Phosphate Company* (USGS, 2020a). The number of domestic manufacturing locations has fluctuated between 2010 and 2019, varying between four and six facilities. The number of domestic manufacturing locations shown in Figure 2 represents operating facilities as of 2017 (USGS, 2020a). Supply of NSF/ANSI Standard 60 certified fluorosilicic acid for use in drinking water treatment is widely distributed throughout the U.S. (NSF International, 2021). For a more current listing of manufacturing locations and supplier locations, visit the U.S. Environmental Protection Agency's (EPA's) Chemical Locator Tool (EPA, 2022a).

[1]FSA production, as sourced from phosphate rock, is included in the USGS profile for fluorspar (U.S. Geological Survey. 2020. *2017 Minerals Yearbook: Fluorspar,* https://www.usgs.gov/centers/national-minerals-information-center/fluorspar-statistics-and-information)

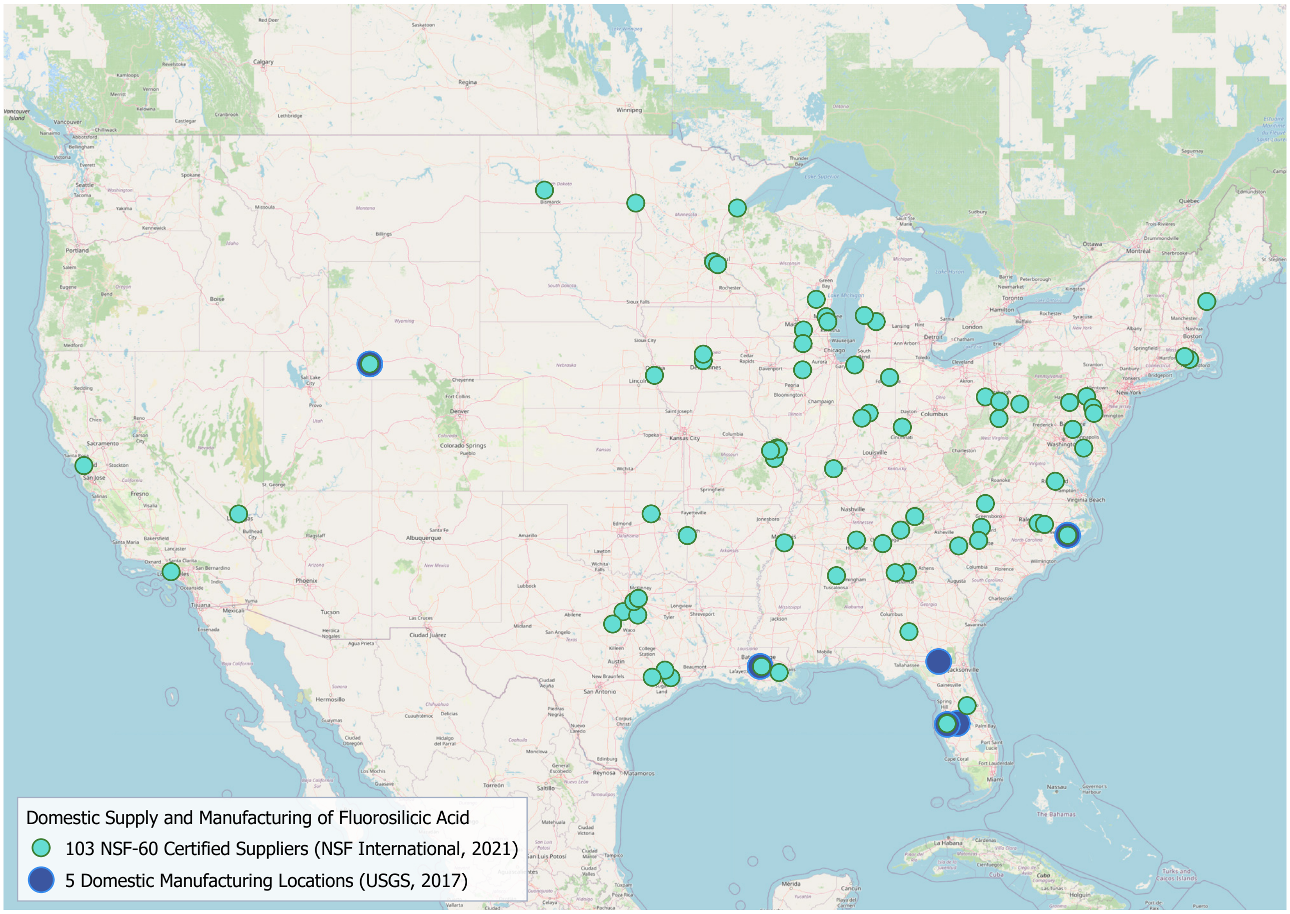


Figure 2. Domestic Supply and Manufacturing of Fluorosilicic Acid

Domestic Consumption

U.S. consumption of FSA in 2019 is estimated at 58 M kg. This estimate includes production of 29 M kg, import of 39 M kg, minus export of 10 M kg (USGS, 2021; USITC, 2021), as shown in Figure 3. Imports and exports represent trade of inorganic acids, NES (HTS Code 2811.19.61), while production data is specific to FSA.

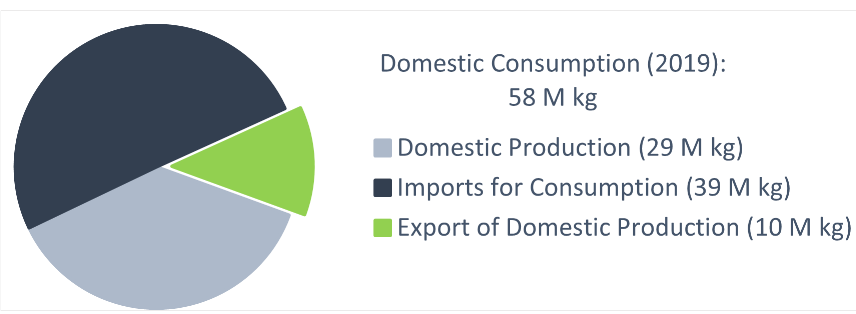


Figure 3. Domestic Production and Consumption of Fluorosilicic Acid in 2019

Trade & Tariffs

Worldwide Trade

Worldwide import and export data for FSA is reported through the World Bank's World Integrated Trade Solutions (WITS) software, as a category representing a class of inorganic acids other than hydrogen fluoride. In

2021, the U.S. ranked ninth worldwide in total exports and fourth in total imports of inorganic acids other than hydrogen fluoride. In 2021, China ranked first worldwide in total exports and total imports (WITS, 2022), as shown in Table 2. Import and export data specific to FSA is unavailable from the referenced sources.

Table 2. WITS Worldwide Export and Import of Inorganic Acids Other than Hydrogen Fluoride, including Fluorosilicic Acid, in 2021

2021 Worldwide Trade Inorganic Acids Other than Hydrogen Fluoride (HS Code 2811.19)			
Top 5 Worldwide Exporters		Top 5 Worldwide Importers	
China	92 M kg	China	71 M kg
Israel	40 M kg	Sweden	67 M kg
Poland	27 M kg	Germany	33 M kg
Germany	15 M kg	**United States**	**31 M kg**
Malaysia	14 M kg	Brazil	17 M kg

Domestic Imports and Exports

Domestic imports and export data are reported by USITC in categories for inorganic acids, NES. Figure 4 summarizes imports for consumption[2] and domestic exports[3] between 2015 and 2020. During this period, the overall quantity of exports and imports remained relatively steady, with imports for consumption exceeding domestic exports. Over this five-year period, China was the primary recipient of domestic exports and the primary source of imports (USITC, 2021).

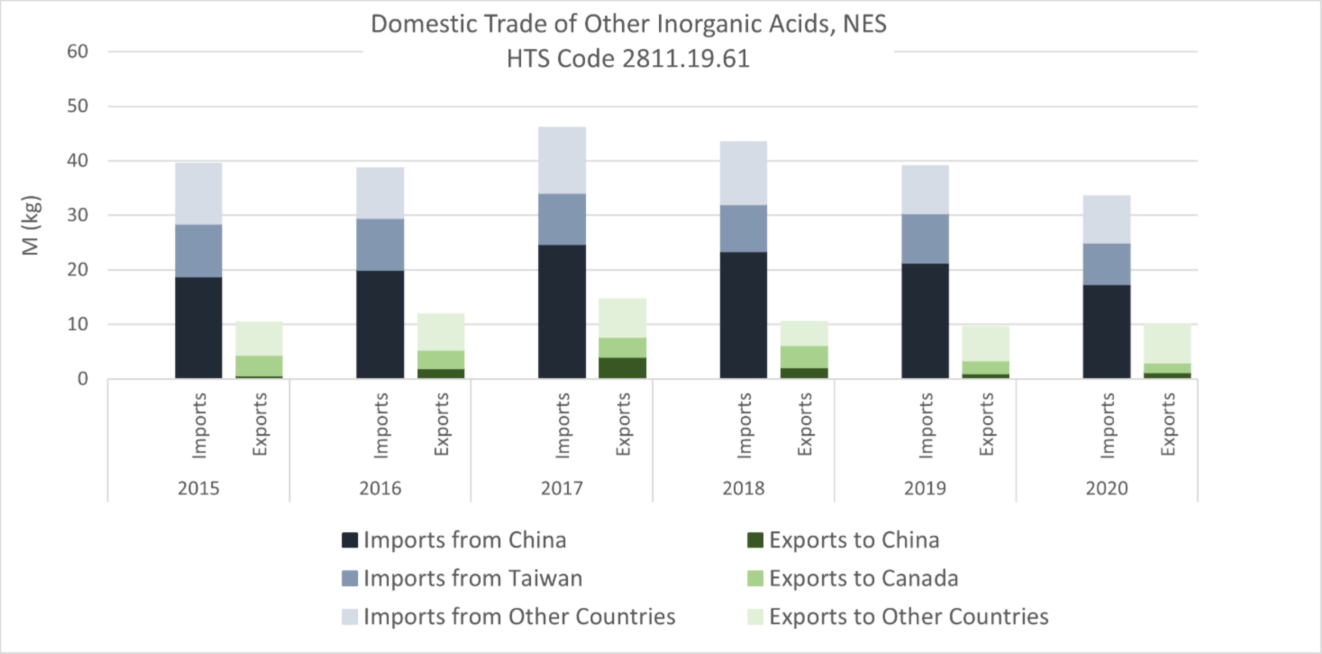


Figure 4. USITC Domestic Import and Export of Inorganic Acids, NES, including Fluorosilicic Acid, between 2015 and 2020

[2] Imports for consumption are a subset of general imports, representing the total amount cleared through customs and entering consumption channels, not anticipated to be reshipped to foreign points, but may include some reexports.
[3] Domestic exports are a subset of total exports, representing export of domestic merchandise which are produced or manufactured in the U.S. and commodities of foreign origin which have been changed in the U.S.

Tariffs

There is a 4.2% general duty for import of FSA, and an additional 25% duty on imports from China (USITC, 2022), as summarized in Table 3.

Table 3. 2020 Domestic Tariff Schedule for Inorganic Acids, NES, including Fluorosilicic Acid

HS Code	General Duty	Additional Duty – China (Section 301 Tariff List)	Special Duty
2811.19.61	4.2%	25%	Free (A, AU, BH, CA, CL, CO, D, E, IL, JO, KR, MA, MX, OM, P, PA, PE, SG)[4]

Market History & Risk Evaluation

History of Shortages

As noted, FSA is most commonly produced by capturing and processing the offgas from the wet method of phosphoric acid production. However, the infrastructure necessary to capture and process the offgas is not present at all phosphoric acid manufacturing locations, both domestic and worldwide. Disruptions in the supply chains for phosphate rock and phosphoric acid at the facilities that can capture and process the offgas can therefore have a significant impact on availability of FSA.

Phosphate rock is mined in large quantity in a limited number of countries worldwide. In 2017, Morocco, China, and the United States were the leading producers of phosphate rock (USGS, 2020b). The Hubei Province of China, which experienced a prolonged lockdown in 2020 due to the COVID-19 pandemic, is the location of 30% of the country's phosphate production. Similar supply chain disruptions, impacting shipping and transport activities have occurred elsewhere. Though the supply shocks resulting from COVID-19 lockdowns appear to have been temporary, other supply challenges to the phosphate rock market were ongoing in 2022.

In 2020, *Mosaic*, a leading domestic manufacturer of phosphate-based products, petitioned the US Department of Commerce to investigate alleged unfair government subsidies of phosphate fertilizers produced by Russia and Morocco. *Mosaic* alleged the unfair subsidies increased prices for phosphate in the US, which affected the prices of phosphate-based products such as phosphoric acid. Initial action in 2020 by the Department of Commerce led to a shift in trade flow and an increase in the domestic price for phosphate, a trend that continued through 2021 (INN, 2021).

The American Water Works Association (AWWA) released a memo in 2012 remarking on ongoing shortages of FSA supplied to water utilities. AWWA noted that FSA shortages were cyclical and typically seen after June, and recommended utilities ensure full storage by June each year and prepare for increased lead times during warmer months (AWWA, 2012).

[4] Symbols used to designate the various preference programs and trade agreements. A full list of special trade agreements and associated acronyms can be found at https://help.cbp.gov/s/article/Article-310?language=en_US and the General Notes Section of the Harmonized Tariff Schedule https://hts.usitc.gov/current

Risk Evaluation

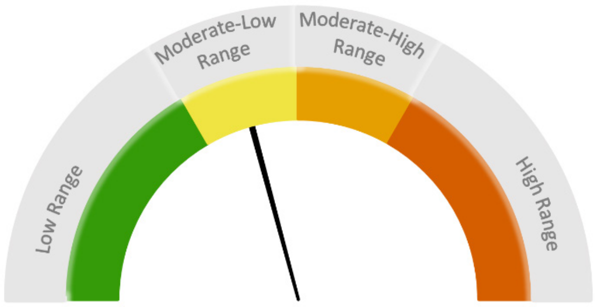
The complete risk evaluation methodology is described in *Understanding Water Treatment Chemical Supply Chains and the Risk of Disruptions* (EPA, 2022b). The risk rating is calculated as the product of the following three risk parameters:

Risk = Criticality x Likelihood x Vulnerability	
Criticality	Measure of the importance of a chemical to the water sector
Likelihood	Measure of the probability that the chemical will experience a supply disruption in the future, which is estimated based on past occurrence of supply disruptions
Vulnerability	Measure of the market dynamics that make a chemical market more or less resilient to supply disruptions

The individual parameter rating is based on evaluation of one or more attributes of the chemical or its supply chain. The ratings and drivers for these three risk parameters are shown below in Table 4.

Table 4. Supply Chain Risk Evaluation for Fluorosilicic Acid

Risk Parameter Ratings and Drivers		
Criticality — Low	**Likelihood — High**	**Vulnerability — Moderate-High**
FSA has widespread but discretionary application for fluoridation and is not used as a precursor to manufacture other water treatment chemicals.	The water sector has experienced widespread FSA supply disruptions in the past. FSA is produced at a small number of facilities concentrated in Florida and Louisiana. The facilities that produce FSA as a byproduct of phosphoric acid production routinely experience periods of planned downtime, which results in recurring volatility in the supply of FSA.	Limited domestic manufacturing concentrated in select geographic areas, strong reliance on imports with high tariffs, and limited shelf life lead to an elevated vulnerability. The lack of considerable competing uses for FSA slightly reduces the vulnerability.
Risk Rating: Moderate-Low		



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