Sodium Hydroxide

NaOH (liquid)

Direct Use Chemical Precursor Chemical

Inputs to Manufacturing Process:
Sodium Chloride

Derivative Water Treatment Chemicals:
Aluminum Hydroxide
Monosodium Phosphate
Calcium Hypochlorite
Disodium Phosphate
Sodium Hypochlorite
Sodium Silicate
Sodium Chlorite

% of Total Domestic Consumption Attributed to Water Sector:
Approximately 3%

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

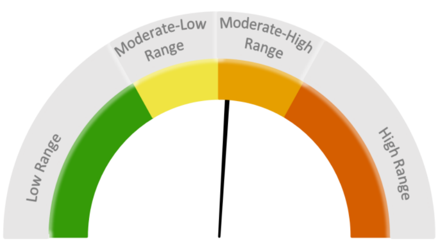
Product Family:
Chlor-alkali

CAS No.:
1310-73-2

Shelf Life:
24 Months

RISK OF SUPPLY DISRUPTION (Assessed in 2022)

RISK RATING: Moderate-High



RISK DRIVERS

Sodium hydroxide is co-produced with chlorine through the chlor-alkali process, and demand for chlorine generally drives chlor-alkali production output. This can create an uneven supply of sodium hydroxide. Furthermore, unplanned and planned chlor-alkali production outages have resulted in supply disruptions.

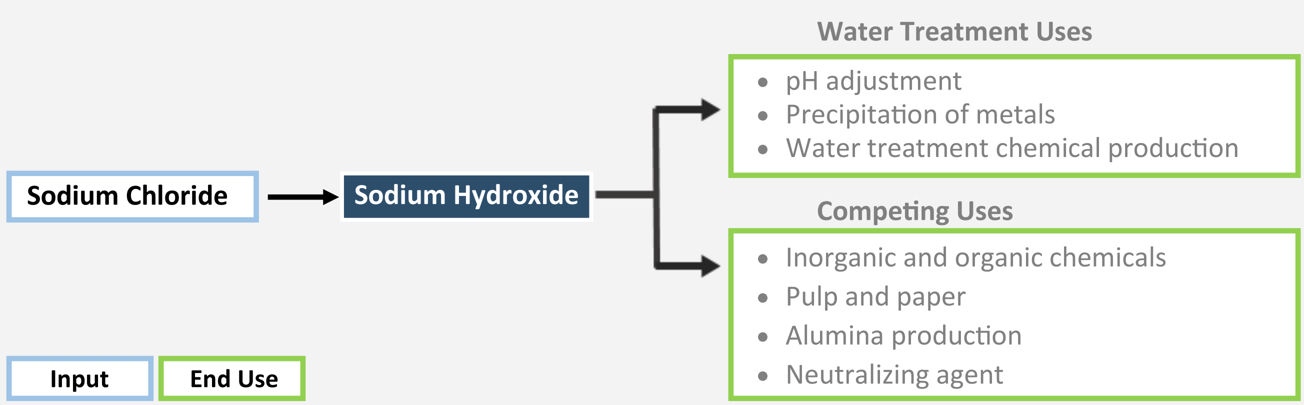
RISK PARAMETERS

Criticality: High. Essential for pH adjustment and production of water treatment chemicals.

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

Vulnerability: Low. Distributed domestic manufacturing and supply. Loss of production capacity could increase vulnerability.

MANUFACTURING PROCESS



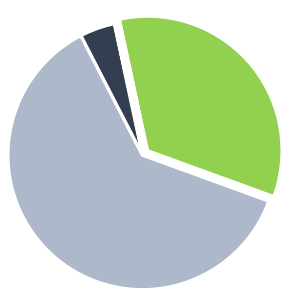
DOMESTIC PRODUCTION AND CONSUMPTION, AND INTERNATIONAL TRADE

Domestic Manufacturing Locations (2019):
41, distributed throughout the U.S.

International Trade (2019)

Primary Trading Partner (Imports): Taiwan

Primary Trading Partner (Exports): Brazil



Domestic Consumption (2019):
6,046 Million kg

- Domestic Production (11,627 M kg)
- Imports for Consumption (792 M kg)
- Export of Domestic Production (6,373 M kg)

Product Description

Sodium hydroxide (NaOH) is an inorganic, strong base that is widely used for pH adjustment. It is a foundational product of the chlor-alkali industry, primarily manufactured through electrolysis of a sodium chloride brine. The majority of sodium hydroxide manufactured in the U.S. is used in organic and inorganic chemical production.

Use in Water Treatment

Sodium hydroxide is used in water treatment for pH adjustment and precipitation of metals (AWWA, 2019; NCBI, 2020).

Use as a Precursor to Other Water Treatment Chemicals

Sodium hydroxide is used to manufacture aluminum hydroxide, calcium hypochlorite, sodium hypochlorite, sodium chlorite, mono- and disodium phosphate, and sodium silicate.

Other Applications

Sodium hydroxide has a wide range of applications. The leading uses of sodium hydroxide in North America are inorganic and organic chemical manufacturing, and pulp and paper manufacturing. Other applications include manufacturing of soap, bleach, plastics, pharmaceuticals, and alumina production. Sodium hydroxide is also used as a neutralizing agent in many industrial applications, including the manufacturing of synthetic materials (NCBI, 2020; IHS Markit, 2017; Westlake Corporation, 2018).

Primary Industrial Consumers

In 2015, the use of sodium hydroxide for organic chemical synthesis accounted for 23% of North American consumption, followed by pulp and paper manufacturing and inorganic chemical production, which each accounted for 22% of North American consumption. A variety of specialty applications including alumina production accounted for the remaining 33%. All water treatment applications, including wastewater treatment and drinking water treatment, account for 3% of North American consumption (IHS Markit, 2017).

Manufacturing, Transport, & Storage

Manufacturing Process

Sodium chloride is the primary raw material used to produce sodium hydroxide. The majority of sodium hydroxide is produced using the chlor-alkali process, which involves passing a direct electric current through a sodium chloride brine (i.e., electrolysis), converting chloride ions to elemental chlorine at the anode while sodium ions and hydrogen gas collect at the cathode to react and form sodium hydroxide (The Chlorine Institute, 2014). The general equation for this process is shown in Figure 1. Sodium hydroxide is separated from the solution using one of the following three methods: (1) the diaphragm method; (2) the membrane method; or (3) the mercury cell method. The diaphragm method is the most common separation process used in North America (The Chlorine Institute, 2014; Westlake Corporation, 2018).

Sodium Chloride Brine	$\rightarrow$	Chlorine Gas	+	Hydrogen Gas	+	Sodium Hydroxide
$2NaCl + 2H_2O$	$\rightarrow$	Cl_2	+	H_2	+	$2NaOH$
		$\downarrow$		$\downarrow$		$\downarrow$
		Anode		Cathode		Cathode

Figure 1. Chemical Equation for the Reaction to Manufacture Sodium Hydroxide

Sodium hydroxide can also be produced from trona; the primary, natural source of sodium carbonate in North America. Sodium hydroxide manufactured from trona is formed when sodium carbonate is combined with a lime (calcium hydroxide) solution in a precipitation reaction forming a sodium hydroxide solution and calcium carbonate precipitate (Eldoma et al., 2013; Genesis Alkali, 2017).

Product Transport

Sodium hydroxide can be transported in bulk or smaller containers by truck, rail, barge, and ship (Westlake Corporation, 2018).

Storage and Shelf Life

Sodium hydroxide is highly reactive and corrosive, and thus should be stored in non-reactive storage vessels at room temperature in a dry, cool place to avoid solidification. When stored properly, sodium hydroxide in solution can have a shelf life of 24 months, depending on concentration and size of storage container (CORECHEM, 2017; Puritan Products, 2017).

Domestic Production & Consumption

Domestic Production

Production data was collected from the Chlorine Institute, while trade data was collected from the U.S. International Trade Commission (USITC) Dataweb, as characterized in Table 1. Both production data and trade data are specific to sodium hydroxide in an aqueous solution.

Table 1. Sodium Hydroxide Production and Trade Data Sources

Production and Trade Data			
Category	**Data Source**	**Identifier**	**Description**
Domestic Production	The Chlorine Institute	CAS No.: 1310-73-2	Sodium Hydroxide (Aqueous)
Imports and Exports	U.S. International Trade Commission	HS Code: 2815.12	Sodium Hydroxide (Aqueous)

Total U.S. domestic manufacturing of sodium hydroxide was approximately 11,627 million kg (M kg) in 2019 (The Chlorine Institute, 2020). The majority of domestic commercial manufacture of sodium hydroxide takes place at chlor-alkali facilities located throughout the contiguous U.S. Many of these facilities are owned by a relatively small number of companies including *Olin Corporation*, *Formosa Plastics Group*, *Westlake Corporation*, and *Oxy Chemical Corporation* (The Chlorine Institute, 2020). *Westlake Corporation* and *Formosa Plastics Group* are leading global and domestic manufacturers of sodium hydroxide. While *Westlake Corporation* and *Formosa Plastics Group* manufacture and distribute millions of tons of sodium hydroxide each year, a significant percentage of the sodium hydroxide manufactured serves as feedstock for the derivative products these companies produce (Formosa Plastics Group, 2021; Westlake Corporation, 2018). The number of domestic manufacturing locations shown in Figure 2 represents operating facilities as of 2019. Supply of NSF/ANSI Standard 60 certified sodium hydroxide 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).

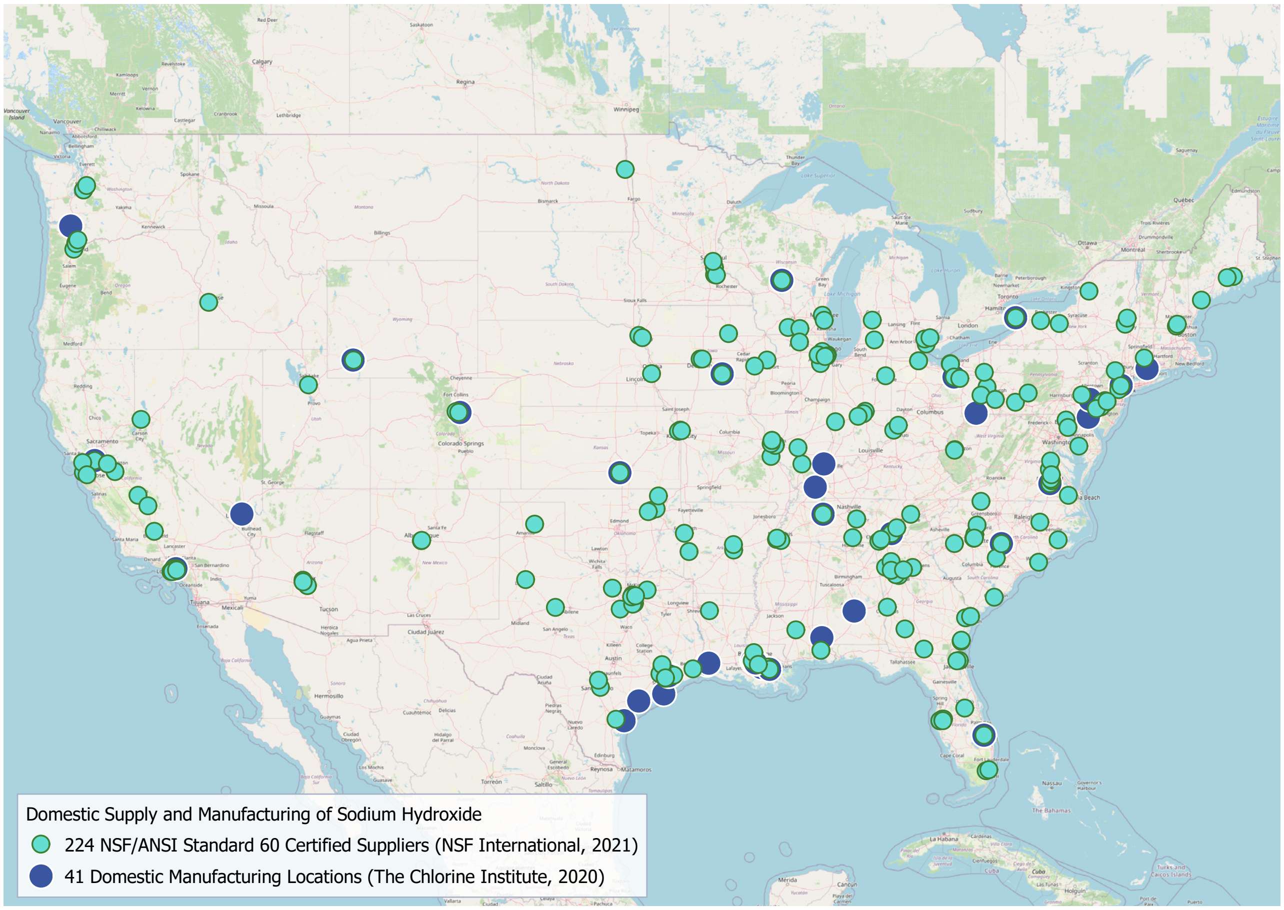


Figure 2. Domestic Supply and Manufacturing of Sodium Hydroxide

Domestic Consumption

U.S. consumption of sodium hydroxide in 2019 is estimated at 6,046 M kg. This includes production of 11,627 M kg, import of 792 M kg, minus export of 6,373 M kg (The Chlorine Institute, 2020; USITC, 2021), as shown in Figure 3.

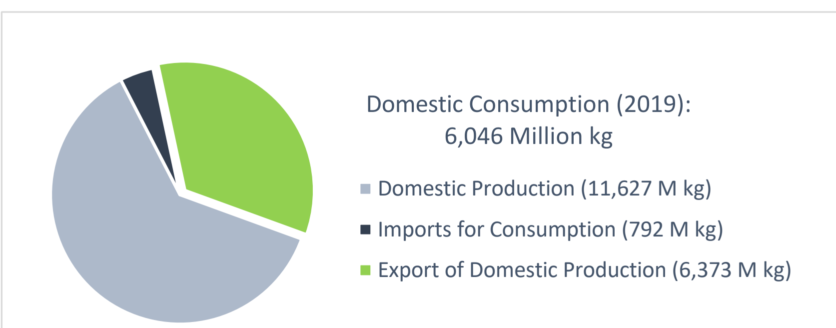


Figure 3. Domestic Production and Consumption of Aqueous Sodium Hydroxide in 2019

Trade & Tariffs

Worldwide Trade

Worldwide import and export data for sodium hydroxide are reported through the World Bank's World Integrated Trade Solutions (WITS) software, as a category specific to sodium hydroxide (aqueous solution). In 2021, U.S. ranked first worldwide in total exports and second in total imports of sodium hydroxide. In 2021, Netherlands ranked first worldwide in total imports (WITS, 2022), as shown in Table 2. The quantity of sodium hydroxide imported by Brazil, a country which imports significant quantities of sodium hydroxide from the U.S., was not reported through WITS in 2021.

Table 2. WITS Worldwide Export and Import of Sodium Hydroxide in 2019

2021 Worldwide Trade Sodium Hydroxide (Aqueous Solution) (HS Code 2815.12)			
Top 5 Worldwide Exporters		Top 5 Worldwide Importers	
United States	**5,749 M kg**	Netherlands	1,881 M kg
Netherlands	1,980 M kg	**United States**	**1,146 M kg**
Japan	1,951 M kg	Finland	871 M kg
France	1,140 M kg	Sweden	712 M kg
China	1,094 M kg	Spain	626 M kg

Domestic Imports and Exports

Domestic import and export data are reported by USITC in categories specific to sodium hydroxide in aqueous solution. Figure 4 summarizes imports for consumption[1] and domestic exports[2] of sodium hydroxide between 2015 and 2020. During this period, the overall quantity of exports and imports remained relatively steady, with domestic exports exceeding imports for consumption. Over this five-year period, Brazil was the primary recipient of domestic exports while Taiwan was the primary source of imports (USITC, 2021). Unlike chlorine, sodium hydroxide is easily stored and transported, which allows for greater utilization of international trade.

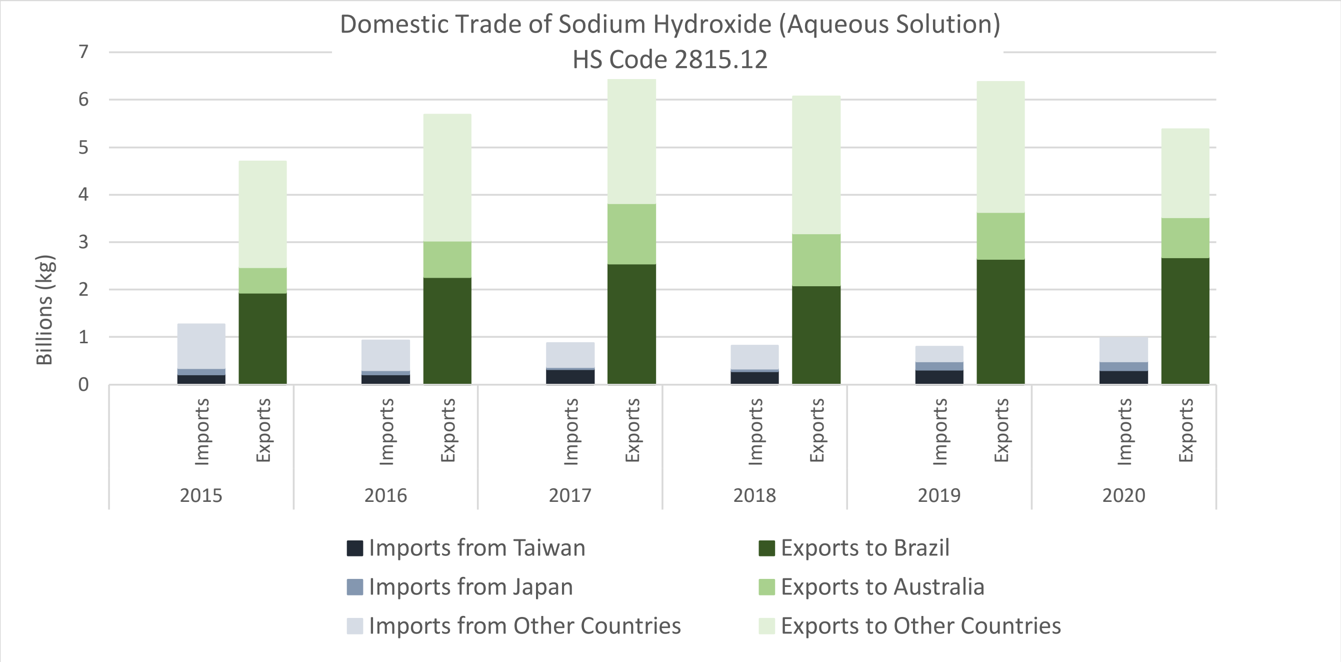


Figure 4. USITC Domestic Import and Export of Sodium Hydroxide between 2015 and 2020

[1] 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.
[2] 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 no general duty for import of sodium hydroxide, however, there is an additional 25% duty on imports from China (USITC, 2022), as summarized in Table 3. China, one of the largest chlor-alkali producing nations, is expected to drive future growth in chlor-alkali production (Kreuz et al., 2022).

Table 3. Domestic Tariff Schedule for Sodium Hydroxide in 2020

HS Code	General Duty	Additional Duty – China (Section 301 Tariff List)	Special Duty
2815.12	None	25%	None

Market History & Risk Assessment

History of Shortages

Chlor-alkali producers generally set chlor-alkali production around demand for chlorine. In the past this has created uneven supply and demand patterns for the sodium hydroxide market. When demand for chlorine decreased during and after the Great Recession (2007-2009), a reduction in chlor-alkali production followed. The resulting sodium hydroxide supply disruption resulted in local shortages impacting the water sector (Henderson et al., 2009). Another shortage occurred in 2021 when Winter Storm Uri directly hit the Gulf Coast region resulting in a temporary loss of approximately 28% of domestic chlor-alkali production capacity (The Chlorine Institute, 2021). Furthermore, in spring and summer of 2021, a number of chlor-alkali production facilities experienced significant equipment failures resulting in additional, temporary losses in production capacity. While some of these impacted facilities were located in the Gulf Coast region, others were located in West Virginia, Utah, and Washington. Later in the summer of 2021, there was a permanent reduction in chlor-alkali production capacity at facilities located in New York, Alabama, Louisiana, and Texas. The reductions in chlor-alkali production capacity that occurred in 2021 were compounded by the impacts of COVID-19 (Powder and Bulk Solids, 2021; Prohaska, 2021).

Risk Evaluation

The complete risk assessment 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:

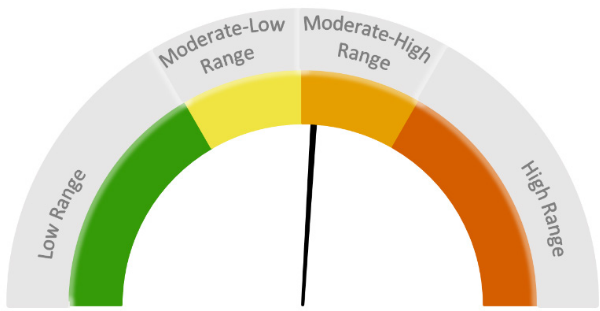
Risk = Criticality x Likelihood x Vulnerability	
Criticality	Measure of the importance of a chemical to the water sector
Likelihood	Measure of the probability that the chemical will experience a supply disruption in the future, which is estimated based on past occurrence of supply disruptions
Vulnerability	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 Sodium Hydroxide

Risk Parameter Ratings and Drivers		
Criticality — High	**Likelihood — High**	**Vulnerability — Low**
Sodium hydroxide is essential to the water sector and has widespread application for pH adjustment. It is a precursor in the production of several other critical water treatment chemicals.	The water sector has experienced regional sodium hydroxide supply disruptions in the past. Uneven supply and demand due to the demand for chlorine driving chlor-alkali production, combined with unplanned and planned chlor-alkali production outages, have led to sodium hydroxide supply disruptions.	Strong domestic manufacturing capabilities and a distributed manufacturing base provide some resilience to supply disruptions. However, chlor-alkali facility closures in 2021 and the potential for future losses in production capacity could increase vulnerability.

Risk Rating: Moderate-High



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