Anhydrous Ammonia

NH_3

(liquified gas)

D Direct Use Chemical P Precursor Chemical

Inputs to Manufacturing Process:
Hydrogen Nitrogen

Derivative Water Treatment Chemicals:
Ammonium Hydroxide
Carbon Dioxide

% of Total Domestic Consumption Attributed to Water Sector:
Less than 2%

Understanding Chemical Supply Chains

Map of Suppliers & Manufacturers

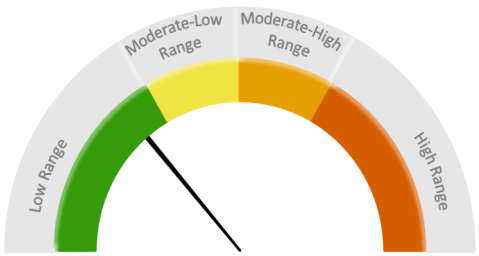
Product Family:
Fossil Fuels

CAS No.: 7664-41-7

Shelf Life:
24 Months

RISK OF SUPPLY DISRUPTION (Assessed in 2022)

RISK RATING: Low



RISK DRIVERS

Anhydrous ammonia is the principal source of nitrogen in fertilizer and though it is widely manufactured, the majority is intended for use as fertilizer. The primary input is natural gas, which may fluctuate in availability and price. The production process is highly energy-intensive.

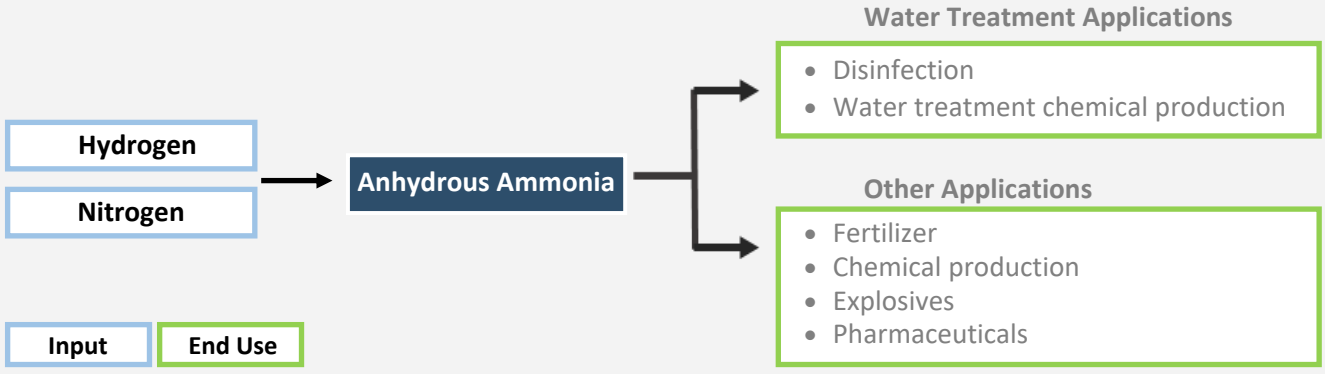
RISK PARAMETERS

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

Likelihood: Low. The water sector has not experienced an anhydrous ammonia supply disruption between 2000 and 2022.

Vulnerability: Low. Widely distributed domestic manufacturing and supply.

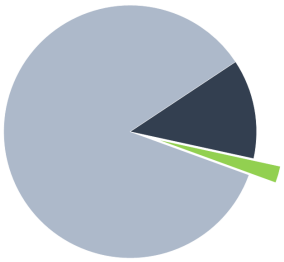
MANUFACTURING PROCESS



DOMESTIC PRODUCTION AND CONSUMPTION, AND INTERNATIONAL TRADE

Domestic Manufacturing Locations (2015):
35, distributed throughout the U.S.

International Trade (2019)
Primary Trading Partner (Imports):
Trinidad & Tobago
Primary Trading Partner (Exports): Chile, Mexico



Domestic Consumption (2019): 15,182 M kg

- Domestic Production (13,500 M kg)
- Imports for Consumption (2,020 M kg)
- Export of Domestic Production (338 M kg)

Product Description

Anhydrous ammonia (NH_3), an inorganic chemical and toxic gas, is widely used in conjunction with chlorine for secondary disinfection. It is the primary source of nitrogen in fertilizer, commercially produced as a byproduct of the steam methane reforming process. The majority of anhydrous ammonia manufactured in the U.S. is used in fertilizer production.

Use in Water Treatment

Anhydrous ammonia is directly used in conjunction with chlorine to produce chloramines for secondary disinfection (AWWA, 2015).

Use as a Precursor to Other Water Treatment Chemicals

Anhydrous ammonia is used to manufacture ammonium hydroxide and is an important source of carbon dioxide which is produced as a byproduct in the manufacturing process.

Other Applications

Anhydrous ammonia is used widely and in large quantities for fertilizer production, either applied directly below the soil surface or as part of a fertilizer formulation. It is also used in the production of chemicals such as nitric acid, household cleaners, refrigerant gas, paper and fibers, plastics, pharmaceuticals, and explosives (NCBI, 2020; USGS 2021a).

Primary Industrial Consumers

In 2018, approximately 88% of the anhydrous ammonia produced and imported into the U.S. was used as the primary nitrogen source for fertilizer. Production of nitric acid and polyamides such as nylon are estimated to each account for approximately 5% of domestic consumption, while the remaining 2% is used for explosives, pharmaceuticals, and various other chemical products (Boerner, 2019; NCBI, 2020; USGS 2021a).

Manufacturing, Transport, & Storage

Manufacturing Process

Anhydrous ammonia can be produced by reacting hydrogen and nitrogen at elevated temperature and pressure in the presence of an iron catalyst (EPA, 2020; Kramer, 2004). Approximately 75-80% worldwide commercial anhydrous ammonia is produced as a by-product in the steam methane reforming process. In the Unites States, natural gas is the primary source for most commercial plants (Kramer, 2004). The first step in this process involves removal of sulfur compounds from the natural gas stream. The desulfurized gas stream is then fed into two reforming steps, where steam (water source) and air (nitrogen source) are reacted with methane (hydrogen source) in the natural gas feedstock to form hydrogen and nitrogen, and other gases. The process stream is then compressed and passed over a catalyst where nitrogen and hydrogen react to form anhydrous ammonia, as presented in Figure 1. The anhydrous ammonia is recovered as a steam, and as the gas is cooled it is stored under pressure as a liquified gas. Unreacted nitrogen and hydrogen are separated and recycled to further enhance the quality of the ammonia product prior to storage and shipping.

Nitrogen	+	Hydrogen	Catalyst	Anhydrous Ammonia
N_2	+	$3H_2$	$\rightarrow$	$2NH_3$

Figure 1. Chemical Equation for the Reaction to Manufacture Anhydrous Ammonia

Product Transport

Anhydrous ammonia is very corrosive and causes severe health effects which dictate how it can be transported. Liquified anhydrous ammonia is sold in bulk quantities and primarily delivered by pipeline or specialized railcars to suppliers who may repackage and see the product directly to consumers. Transport of anhydrous ammonia must adhere to the appropriate methods and regulations related to its status as a toxic substance, and transit routes designated for anhydrous ammonia must go through an approval process. Bulk transport by rail is very significant. There are limited number of domestic producers, and long-haul shipment of anhydrous ammonia is often accomplished via rail (Branscomb et al., 2010).

Storage and Shelf Life

Anhydrous ammonia can be pressurized and cooled to a liquified gas and stored in pressure vessels. Small, pressurized cylinders may be used by smaller water systems, while larger systems may require bulk deliveries. Pressurized storage vessels should be stored in a cool place away from direct sunlight. When stored properly, anhydrous ammonia can have a shelf life of 24 months, depending on purity and size of storage container (CF, 2016).

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. Both production and trade data are specific to anhydrous ammonia.

Table 1. Anhydrous Ammonia Production and Trade Data Sources

Production and Trade Data			
Category	**Data Source**	**Identifier**	**Description**
Domestic Production	U.S. Geological Survey	CAS No.: 7664-41-7	Anhydrous Ammonia
Imports and Exports	U.S. International Trade Commission	HS Code: 2814.10	Anhydrous Ammonia

Total U.S. domestic production of anhydrous ammonia was approximately 13,500 million kilograms (M kg) in 2019 (USGS, 2021b). Domestic commercial manufacture of anhydrous ammonia takes place in 17 states throughout the country. This is largely based on proximity to large reserves of natural gas. The largest domestic producer of anhydrous ammonia by quantity is *CF Industries*, with 5 production facilities in Louisiana, Oklahoma, Mississippi, and Iowa (USGS 2021a). The number of domestic manufacturing locations shown in Figure 2 represents operating facilities as of 2015. Supply of NSF/ANSI Standard 60 certified anhydrous ammonia for use in drinking water treatment is 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).

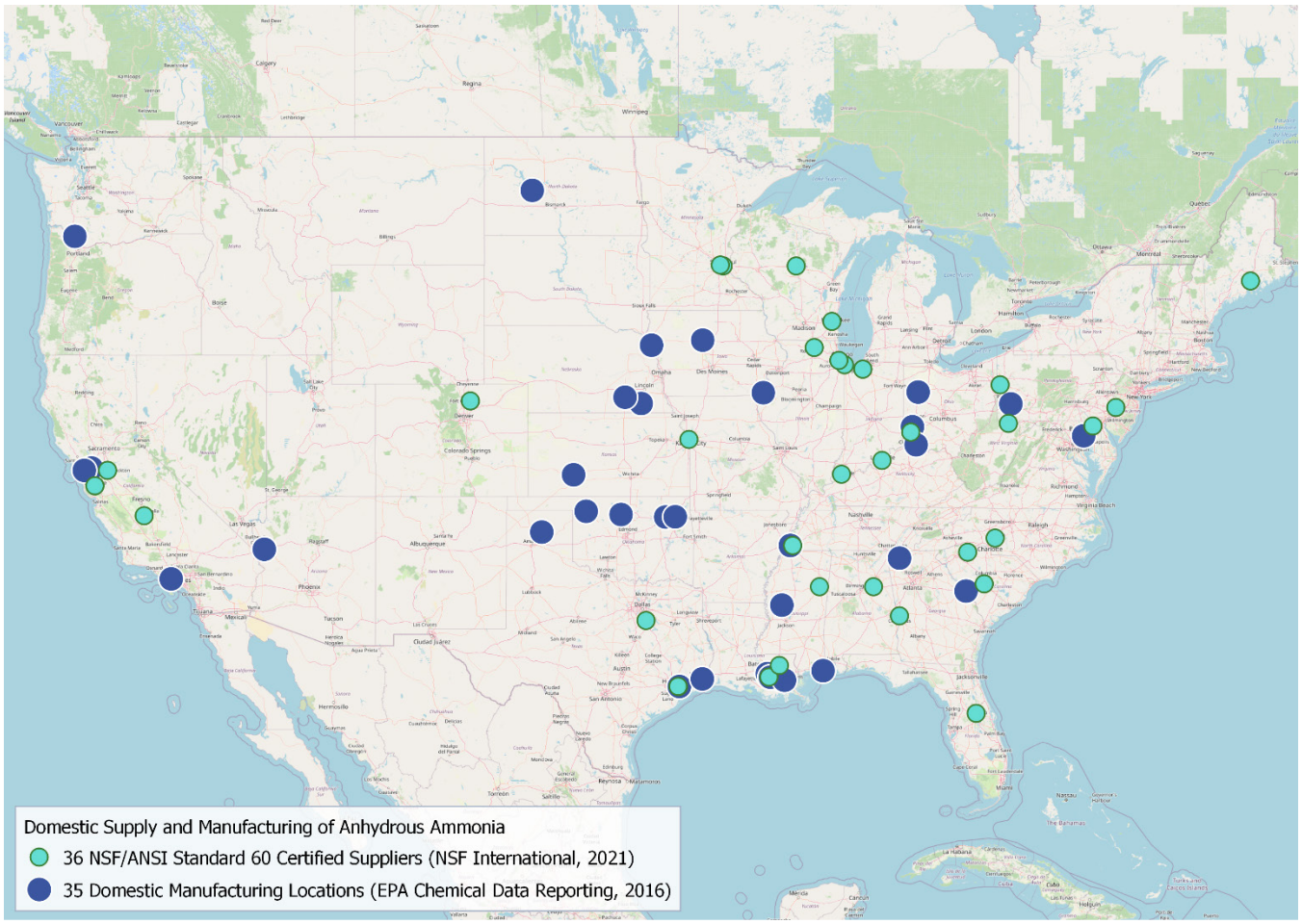


Figure 2. Domestic Supply and Manufacturing of Anhydrous Ammonia

Domestic Consumption

U.S. consumption of anhydrous ammonia in 2019 is estimated at 15,182 M kg. This estimate includes production of 13,500 M kg, import of 2,020 M kg, minus export of 338 M kg (USGS, 2021b), as shown in Figure 3.

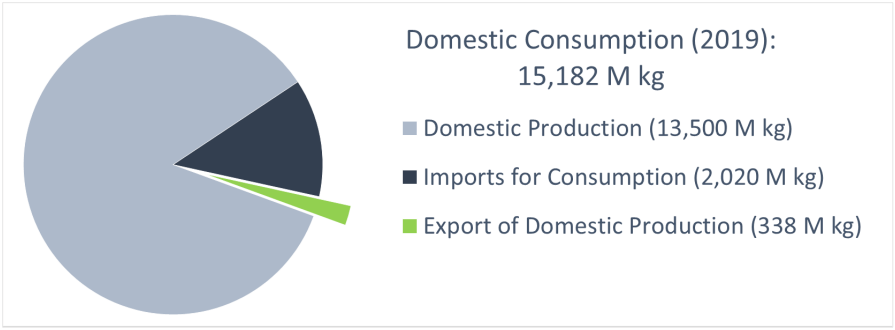


Figure 3. Domestic Production and Consumption of Anhydrous Ammonia in 2019

Trade & Tariffs

Worldwide Trade

Worldwide import and export data for anhydrous ammonia are reported through the World Bank's World Integrated Trade Solutions (WITS) software, as a category specific to anhydrous ammonia. In 2021, the U.S.

ranked first worldwide in total imports of anhydrous ammonia. In 2021, the Russian Federation ranked first worldwide in total exports while the U.S. ranked 11th (WITS, 2022), as shown in Table 2.

Table 2. WITS Worldwide Export and Import of Anhydrous Ammonia in 2021

2021 Worldwide Trade Anhydrous Ammonia (HS Code 2814.10)			
Top 5 Worldwide Exporters		Top 5 Worldwide Importers	
Russian Federation	4,400 M kg	**United States**	**2,500 M kg**
Trinidad and Tobago	3,200 M kg	India	2,400 M kg
Saudi Arabia	2,900 M kg	Morocco	1,700 M kg
Indonesia	1,800 M kg	Belgium	1,000 M kg
Canada	1,200 M kg	Turkey	839 M kg

Domestic Imports and Exports

Domestic imports and export data are reported by USITC in categories specific to anhydrous ammonia. Figure 4 summarizes imports for consumption[1] and domestic exports[2] of anhydrous ammonia between 2015 and 2020. During this period, the overall quantity of exports remained relatively steady, and the overall quantity of imports gradually decreased, with imports for consumption exceeding domestic exports. Over this five-year period, Chile and Mexico were the primary recipient of domestic exports while Trinidad and Tobago was the primary source of imports (USITC, 2021).

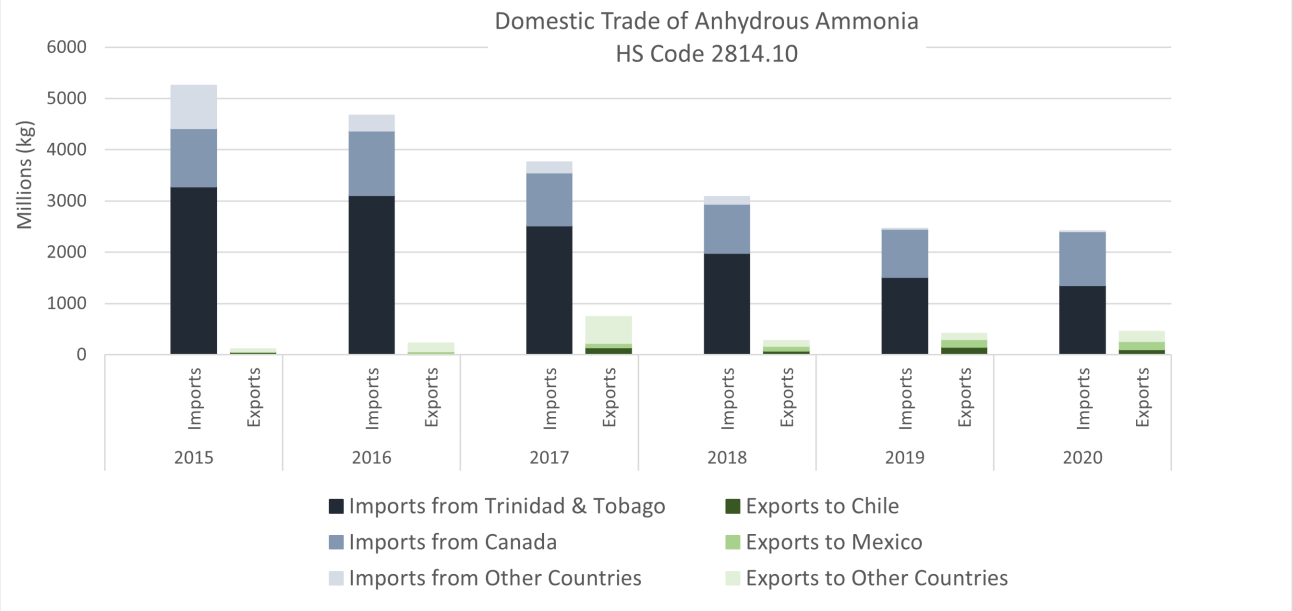


Figure 4. USITC Domestic Import and Export of Anhydrous Ammonia between 2015 and 2020

[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 anhydrous ammonia, however there is an additional 25% duty on imports from China (WITS, 2022), as summarized in Table 3.

Table 3. 2022 Domestic Tariff Schedule for Anhydrous Ammonia

HS Code	General Duty	Additional Duty - China (Section 301 Tariff List)	Special Duty
2814.10	None	25%	None

Market History & Risk Assessment

History of Shortages

Anhydrous ammonia is the primary source of nitrogen in fertilizer, and use in fertilizer dominates domestic consumption. Additionally, the process to manufacture anhydrous ammonia, primarily from natural gas, is energy intensive (Boerner, 2019). Regardless of potential risks, no notable shortages of anhydrous ammonia were identified between 2000 and 2022.

Risk Evaluation

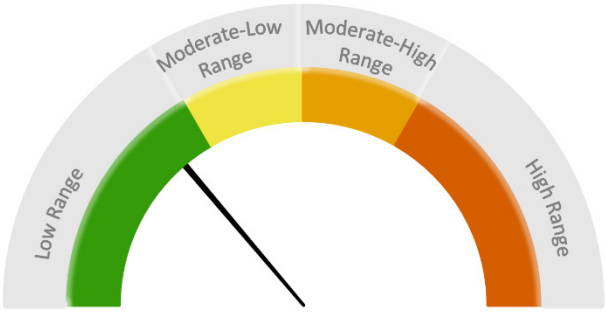
The complete risk evaluation methodology is described in *Understanding Water Treatment Chemical Supply Chains and the Risk of Disruptions* (EPA, 2022b). The risk rating is calculated as the product of the following three risk parameters:

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 Anhydrous Ammonia

Risk Parameter Ratings and Drivers		
Criticality: High	**Likelihood: Low**	**Vulnerability: Low**
Anhydrous ammonia is essential and has widespread application in drinking water treatment for secondary disinfection.	The water sector has not experienced anhydrous ammonia supply chain disruptions between 2000 and 2022.	Though the majority of anhydrous ammonia is intended for use in fertilizer manufacturing, strong domestic manufacturing capabilities and a distributed manufacturing base provide some resilience to supply disruptions.
Risk Rating: Low		



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