Ilmenite

Raw Material

$FeTiO_3$ (solid)

Source of Raw Material: Naturally occurring ore

% of Total Domestic Consumption Attributed to Water Sector: Less than 1%

Product Family: Titanium

CAS No.: 12168-52-4

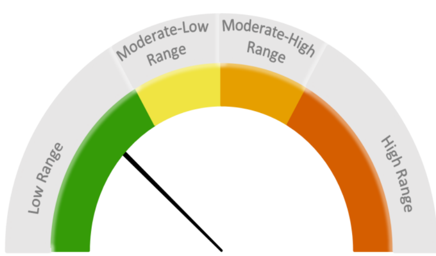
Derivative Water Treatment Chemicals: Ferric Chloride, Ferrous Sulfate

Understanding Chemical Supply Chains

Shelf Life: 60+ Months

RISK OF SUPPLY DISRUPTION (Assessed in 2022)

RISK RATING: Low



RISK DRIVERS

Production of titanium dioxide is the primary (90%) domestic use of ilmenite. Fluctuations in use of titanium dioxide may drive domestic demand for ilmenite. Supply of ilmenite is heavily dependent on imports, for which there is considerable international competition. Imports are primarily from a select number of countries.

RISK PARAMETERS

Criticality: Moderate-Low. Iron chlorides produced as a byproduct of processing ilmenite can be used to manufacture ferric chloride and ferrous sulfate.
Likelihood: Low. No identified ilmenite supply disruptions between 2000 and 2022.
Vulnerability: Moderate-Low. The U.S. is heavily reliant on imports of ilmenite, however, there are numerous sources of imports.

PRODUCTION PROCESS

Mining → Ilmenite

Water Treatment Applications
- Water treatment chemical production

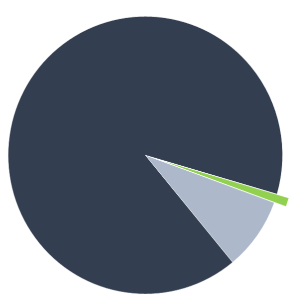
Other Applications
- Titanium dioxide
- Chemical manufacturing
- Titanium metal and alloys
- Welding-rod coating

Input | End Use

DOMESTIC PRODUCTION AND CONSUMPTION, AND INTERNATIONAL TRADE

Domestic Production Locations (2019): 4 locations in Florida, Georgia, and South Carolina.

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



Domestic Consumption (2019): 1,157 M kg

- Domestic Production (100 M kg)
- Imports for Consumption (1,069 M kg)
- Export of Domestic Production (12 M kg)

EPA

Product Description

Ilmenite ($FeTiO_3$), an iron-oxide mineral, is the most common form of titanium-bearing minerals processed for titanium dioxide and titanium metal. Ilmenite accounts for more than 93% of processed titanium ore, and thus information for titanium ores is presented in the profile to represent the specific mineral ilmenite (Woodruff et al., 2017). Though ilmenite is not used directly in water treatment, iron chlorides produced as a byproduct of mineral processing can serve as a raw material in the production of ferric chloride and ferrous sulfate.

Use in Water Treatment

None.

Use as a Precursor to Other Water Treatment Chemicals

Iron chlorides, which may be used to produce ferric chloride, are produced as a byproduct of ilmenite processing when chlorination is used in the process of acid leaching to recover titanium dioxide. When the sulfate process is used to process titanium ores, ferrous sulfate is produced as a waste stream and can be captured for uses such as water treatment.

Other Applications

Use of titanium ores and concentrates is largely tied to production of titanium dioxide. All applications require processing and refining of the ore. Domestically, the majority of titanium mineral concentrates are consumed by titanium dioxide pigment producers, which apply titanium dioxide as a pigment in paints, paper, rubber, plastics, fabrics, and food. Titanium ores and concentrates are also used in manufacturing carbides and other titanium-based chemicals, titanium metal for use in aerospace and other industries, and welding-rod coating (USGS 2021; USGS 2022).

Primary Industrial Consumers

In 2019, approximately 90% of titanium ores and concentrates consumed in the U.S. were used in the production of titanium dioxide, while the remaining 10% were used in manufacturing of carbides and other chemicals, titanium metal, and welding-rod coatings (USGS, 2020).

Manufacturing, Transport, & Storage

Manufacturing Process

Deposits of titanium ores are found throughout the world, primarily in the form of ilmenite, but also less commonly as rutile and leucoxene. Ilmenite accounts for approximately 93% of worldwide titanium mineral production. Ilmenite, an iron oxide, typically contains between 40% and 65% titanium dioxide. Ilmenite is generally mined from surface or near-surface deposits, though location and composition are deposit-dependent and impact beneficiation processes. There are numerous processes, including gravity, magnetic, and electrostatic separation, and flotation that may be used to process and upgrade ilmenite. Pretreatment of ilmenite is required for enhanced leaching of titanium dioxide, as ilmenite contains significant quantities of iron that must be removed. Strong acid leaching, with either sulfuric acid or hydrochloric acid is the primary method to separate the iron and other impurities and recover high-grade titanium dioxide.

The primary domestic process for titanium dioxide recovery is the chloride process, or less commonly the sulfate process. The chloride process begins with roasting of ilmenite with gaseous chlorine in a fluidized bed in the presence of petroleum coke as a reducing agent. The titanium tetrachloride is separated from other impurities and oxidized to titanium dioxide or reduced to titanium sponge metal. As the ilmenite is reacted with the chlorine and coke, gaseous iron chlorides, which are later condensed as a liquid, are produced. If low-grade ilmenite is used, a subsequent step of hydrochloric acid leaching may take place to recover higher grade titanium dioxide. The chloride-ilmenite process yields enriched ilmenite ore with a high percentage of titanium dioxide as well as an acidic ferric chloride solution. In the sulfate process, smelted ilmenite is digested with sulfuric acid and hydrolyzed to produce and precipitate titanium dioxide hydrate. A waste stream of ferrous sulfate and sulfuric acid is separated through filtration (El Khalloufi et al., 2021; EPA, 1998; EPA, 2001; NCBI, 2022; USGS, 2021; USGS 2022).

Product Transport

Titanium ore is widely transported by ship, rail, and truck (Woodruff et al., 2017).

Storage and Shelf Life

Ilmenite is stable and non-reactive over a wide range of temperatures. When stored properly and kept dry, ilmenite can have a shelf life in excess of 60 months (MSR, 2019).

Domestic Production & Consumption

Domestic Production

Production data was collected from USGS, while trade data was collected from the U.S. International Trade Commission (USITC) Dataweb, as shown in Table 1. Production data is specific to ilmenite; however trade data are generalized to titanium ores and concentrates. Ilmenite accounts for approximately 93% of worldwide titanium mineral production.

Table 1. Titanium Ores and Concentrates Production and Trade Data Sources

Production and Trade Data			
Category	**Data Source**	**Identifier**	**Description**
Domestic Production	U.S. Geological Survey	CAS No.: 12168-52-4	Ilmenite
Imports and Exports	U.S. International Trade Commission	HTS Code: 2614.00	Titanium Ores and Concentrates

Total U.S. domestic production of titanium ores and concentrates was approximately 100 million kg (M kg) in 2019 (USGS, 2021). While the U.S. does have a relatively large amount of titanium-bearing deposits and resources, the larger titanium deposits do not have high industrial value, as their mineralogy, location, and possible presence of unfavorable trace constituents makes processing economically unfeasible. As a result, the U.S. has had a net reliance on imports for many years. In 2019 there were four active domestic titanium mineral concentrate production locations in the U.S. in Florida, Georgia, and South Carolina (USGS 2020; Woodruff et al., 2017).

Domestic Consumption

U.S. consumption of titanium ores and concentrates in 2019 is estimated at 1,157 M kg. This estimate includes production of 100 M kg, import of 1,069 M kg, and export of 12 M kg (USGS, 2021), as shown in Figure 1.

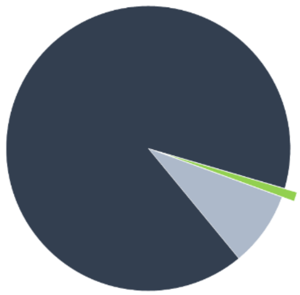


Figure 1. Domestic Production and Consumption of Titanium Ores and Concentrates in 2019

Trade &Tariffs

Worldwide Trade

Worldwide import and export data for titanium ores and concentrates are reported through the World Bank's World Integrated Trade Solutions (WITS) software, as a category for titanium ores and concentrates. In 2021, the U.S. ranked 16th worldwide in total exports and second in total imports of titanium ores and concentrates. In 2021, Mozambique ranked first worldwide in total exports and China ranked first worldwide in total imports (WITS, 2022), as shown in Table 2. While China was the leading titanium ores and concentrates producing nation in 2021, it consumes a significant quantity of domestic production and historically has imported significant quantities from Mozambique and Australia (USGS, 2021).

Table 2. WITS Worldwide Export and Import of Titanium Ores and Concentrates in 2021

2021 Worldwide Trade Titanium Ores and Concentrates (HS Code 2614.00)			
Top 5 Worldwide Exporters		Top 5 Worldwide Importers	
Mozambique	1,253 M kg	China	3,795 M kg
South Africa	672 M kg	**United States**	**985 M kg**
Senegal	588 M kg	Germany	553 M kg
Madagascar	582 M kg	Canada	381 M kg
Ukraine	549 M kg	Norway	344 M kg

Domestic Imports and Exports

Domestic import and export data are reported by USITC in categories for titanium ores and concentrates. Figure 2 summarizes imports for consumption[1] and domestic exports[2] of titanium ores and concentrates between 2015 and 2020. During this period, the overall quantity of imports varied, with a high in 2017. The volume of exports, considerably smaller than the volume of imports, increased from 2 M kg to 28 M kg over the five-year period. Over this five-year period, China took the place of Mexico to become the primary recipients of domestic exports while the primary source of imports shifted from Australia to Madagascar and Mozambique, with Australia and South Africa continuing to supply significant quantities (USITC, 2021).

[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.

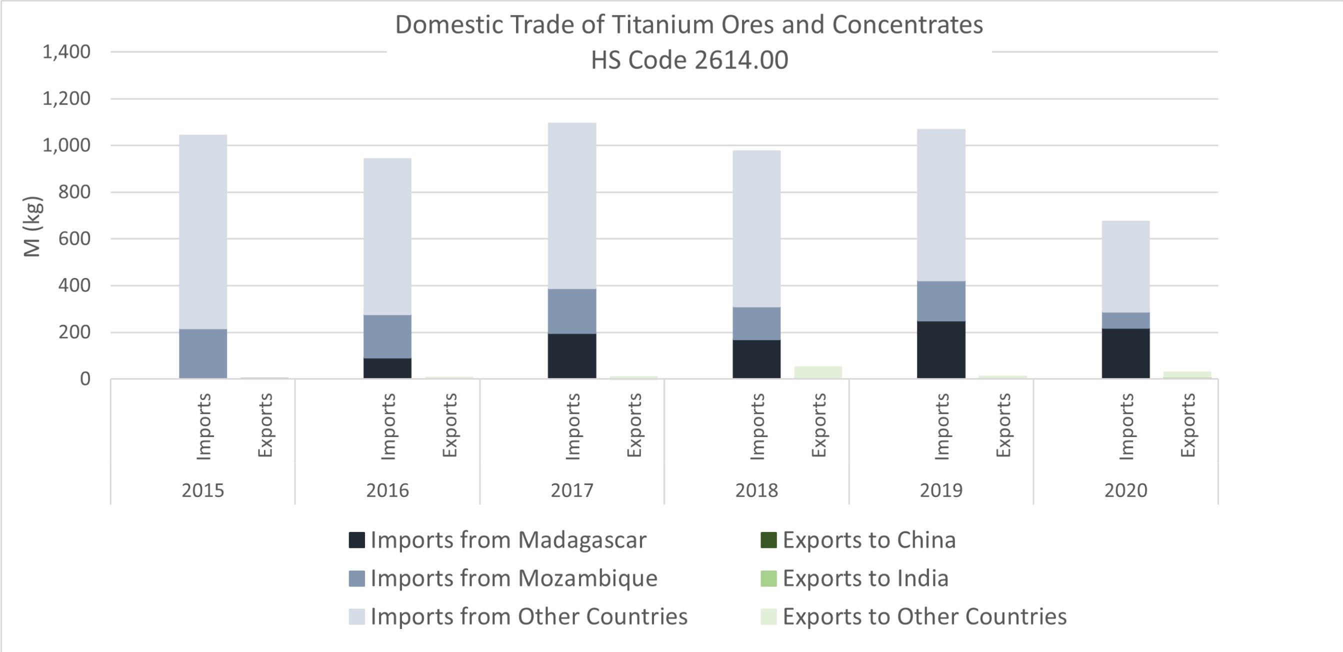


Figure 2. USITC Domestic Import and Export of Titanium Ores and Concentrates between 2015 and 2020

Tariffs

There is no general duty for import of titanium ores and concentrates, however there is an additional 25% duty on imports from China (USITC, 2022), as summarized in Table 3.

Table 3. 2022 Domestic Tariff Schedule for Titanium Ores and Concentrates

HS Code	General Duty	Additional Duty – China (Section 301 Tariff List)	Special Duty
2614.00	None	25%	None

Market History & Risk Evaluation

History of Shortages

The demand for titanium ores and concentrates is tightly tied to demand from industries which utilize titanium dioxide, and domestic production may fluctuate with demand for these products. There is considerable competition for international resources, as mined titanium resources are largely located in a select number of countries. These factors have led to historic price increases in the price for titanium ores and concentrates during periods of fluctuation in demand for derivative products and availability through international trade. Though the U.S. is largely dependent on titanium ores and concentrate imports for production titanium dioxide and titanium, there were no identified supply chain disruptions between 2000 and 2022.

Risk Evaluation

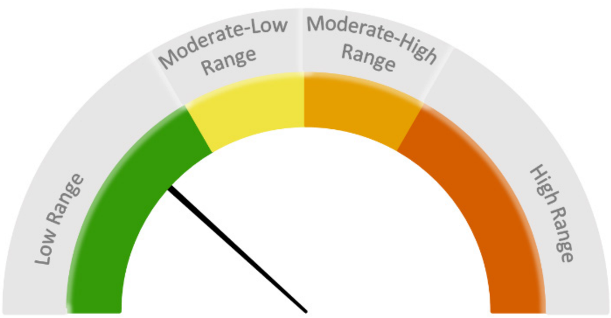
The complete risk assessment methodology is described in *Understanding Water Treatment Chemical Supply Chains and the Risk of Disruptions* (EPA, 2022). The risk rating is calculated as the product of the following three risk parameters:

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 Ilmenite

Risk Parameter Ratings and Drivers		
Criticality — Moderate-Low	**Likelihood — Low**	**Vulnerability — Moderate-Low**
Iron chlorides, which are a byproduct of ilmenite processing, may be used to produce ferric chloride and ferrous sulfate. However, production by this method is not a common a source of iron oxides for North American production.	There were no identified disruptions in the supply of ilmenite between 2000 and 2022.	The U.S. is a net importer of ilmenite, however there are numerous sources of imports, which provides some resilience to supply disruptions. Consumption of titanium dioxide dominates domestic demand for ilmenite.
Risk Rating: Low		



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