2018 Minerals Yearbook

SULFUR [ADVANCE RELEASE]

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Sulfur

By Lori E. Apodaca

Domestic survey data and tables were prepared by Benjamin N. Bryden, statistical assistant.

The United States was the world's second-ranked producer of sulfur behind China in 2018 (table 11). Elemental sulfur and byproduct sulfuric acid, produced as a result of efforts to meet environmental requirements that limit atmospheric emissions of sulfur dioxide, were the dominant sources of sulfur produced around the world.

In 2018, domestic sulfur production was slightly higher and sulfur shipments were the same as those in 2017 (table 1). Elemental sulfur recovered at petroleum refineries was slightly less than that in 2017 and from natural gas operations 6% less (table 3). Producers' stocks, equivalent to 1% of the shipments, decreased slightly (table 1). Byproduct sulfuric acid production and shipments increased by 17% (table 4). Apparent consumption of sulfur in all forms increased by 3% (table 1). Imports of elemental sulfur and sulfuric acid combined increased by 15%, and exports increased by 3%. The average unit value of recovered sulfur in 2018 was 75% higher than that in 2017, resulting in the value of total elemental sulfur shipments increasing by 73% compared with the value of shipments in 2017. The total value of byproduct sulfuric acid shipments increased by 41% (table 1).

Through its major derivative, sulfuric acid, sulfur ranks as one of the most important elements used as an industrial raw material and is of prime importance to every sector of the world's fertilizer and manufacturing industries. Sulfuric acid production is the major end use for sulfur, and consumption of sulfuric acid has been regarded as one of the best indexes of a nation's industrial development. More sulfuric acid is produced in the United States every year than any other inorganic chemical; 25.8 million metric tons (Mt), which is equivalent to about 8.4 Mt of elemental sulfur, was produced in 2018 (Acuity Commodities, written commun., March 30, 2020).

Worldwide, compliance with environmental regulations has contributed to increased sulfur recovery; although for 2018, global sulfur production, in all forms, was slightly lower than that in 2017 (table 11). Recovered elemental sulfur was produced primarily during the processing of natural gas and crude petroleum. Estimated worldwide production of native (naturally occurring elemental) sulfur decreased slightly from that in 2017. In the few countries where iron sulfides (pyrites) remain an important raw material for sulfuric acid production, sulfur production from pyrites was estimated to have been the same as that in 2017.

Since 2005, more than 75% of the world's sulfur production has been a byproduct of natural gas and petroleum processing and contained in byproduct sulfuric acid from nonferrous metal smelting. Some sources of sulfur were unspecified, which means that the material could have been, and likely was, recovered elemental sulfur or byproduct sulfuric acid, increasing the percentage of byproduct sulfur production to about 90% annually. The quantity of sulfur produced from recovered sources was dependent on world demand for fuels, nonferrous metals, and petroleum products rather than for sulfur.

In 2018, global consumption of sulfur was estimated to have increased slightly compared with that in 2017 (Prud'homme, 2018, p. 54). Typically, about 50% is used in fertilizer production, and the remainder is used in a myriad of other industrial uses. Increased consumption was a result of sustained demand in sulfur-based fertilizer production and industrial uses.

Legislation and Government Programs

On October 26, 2018, the International Maritime Organization (IMO) implemented an amendment to support consistent implementation of the plan to reduce maximum allowable levels of sulfur and other pollutants in marine fuels used on the open seas to 0.5% from 3.5%. The IMO amendment, which would be effective on January 1, 2020, and was expected to be enforced beginning on March 1, 2020, would prohibit the carriage of noncompliant fuel oil for propulsion combustion or operation on board a ship unless the ship was fitted with an exhaust-gas-cleaning system ("scrubber"). Installing a scrubber would be considered an acceptable means of meeting the sulfur-limit requirement (International Maritime Organization, 2018).

Production

Recovered Elemental Sulfur.—U.S. production statistics were collected on a monthly basis and published in the U.S. Geological Survey (USGS) monthly sulfur Mineral Industry Surveys. Of the 95 operations to which survey requests were sent, 95 responded, representing 100% of the total production listed in table 1. In 2018, production and shipments were slightly lower than those in 2017. Higher sulfur prices resulted in the value of shipments of recovered material being 73% higher than that in 2017. For 2018, on average, U.S. petroleum refineries operated at 93% of capacity, a slight increase from that in 2017 (U.S. Energy Information Administration, 2019b).

During the 2018 hurricane season, Hurricane Michael had significant negative impacts on oil, natural gas, and sulfur production in the Gulf of Mexico region. Hurricane Michael, a Category 5 storm, made landfall on October 10, 2018, causing reduced production of crude oil by an estimated 680,000 barrels and of natural gas by an estimated 21 million cubic meters. These numbers equated to 40% and 29% of the expected daily Gulf of Mexico crude oil and natural gas production, respectively (Bureau of Safety and Environmental Enforcement, 2018).

Recovered elemental sulfur is a nondiscretionary byproduct from petroleum-refining, natural-gas-processing, and coking plants, meaning it is produced primarily to comply with environmental regulations. These environmental regulations are applicable directly to emissions of sulfur dioxide from processing facilities or indirectly by restricting the sulfur content of fuels sold or used by the facility. Recovered sulfur was produced by 39 companies at 95 plants in 27 States. The capacity of the sulfur recovery operations varied greatly: 35 plants produced more than 100,000 metric tons (t) of elemental sulfur in 2018; 15 produced between 50,000 and 100,000 t; 31 produced between 10,000 and 50,000 t; and 14 produced less than 10,000 t. By source, 93% of recovered elemental sulfur production came from petroleum refineries or satellite plants that treated refinery gases and coking plants; the remainder was produced at natural-gas-treatment plants.

The leading producers of recovered sulfur (all with more than 500,000 t of sulfur production) were, in descending order of production, ExxonMobil Corp., Valero Energy Corp., ConocoPhillips Co. (including its joint venture with Encana Corp.), Marathon Petroleum Corp., Motiva Enterprises LLC, BP p.l.c., CITGO Petroleum Corp., and Chevron Corp. The 47 plants owned by these companies accounted for 72% of recovered sulfur output during the year. Texas, Louisiana, and California, in descending order of production, were the leading producing States, accounting for 68% of recovered sulfur output. Recovered sulfur production by State and district is listed in tables 2 and 3.

In 2018, 5 of the 20 largest oil refineries in the world, in terms of crude-petroleum-processing capacity, were in the United States. In descending order of capacity, they were Motiva's Port Arthur, TX, refinery; Marathon's Galveston Bay, TX, refinery; Marathon's Garyville, LA, refinery; ExxonMobil's Baytown, TX, refinery; and ExxonMobil's Baton Rouge, LA, refinery (Oil & Gas Journal, 2019). The capacity to process large quantities of crude petroleum does not necessarily mean that refineries recover large quantities of sulfur, but all these refineries were major producers of recovered sulfur. Sulfur production depends on installed sulfur recovery capacity as well as the type of crude petroleum refined. Major refineries that process low-sulfur crude petroleum may have relatively low sulfur production. The United States operated 20% of world refining capacity but had almost 33% of world sulfur recovery at these refineries (Oil & Gas Journal, 2018).

U.S. petroleum refining capacity rose by 4% from 2014 through 2018 and by about 13% from 2000 through 2018, mostly from upgrades at existing refineries. In 2018, U.S. refinery capacity was 18.6 million barrels per day, slightly higher than that in 2017. Overall U.S. refinery capacity increased by 35,000 barrels per day (bbl/d) in 2018 (U.S. Energy Information Administration, 2019b). Although sulfur capacity expansion was not specifically mentioned by the U.S. Energy Information Administration, any such expansions would likely include increased sulfur recovery facilities.

PBF Energy, Inc. began construction of a new $100 million hydrogen plant at its Delaware City, DE, petroleum refinery. The hydrogen plant, expected to be operational in late 2019, would allow the refinery to expand the output of the coking section and generate an additional 7,000 to 10,000 bbl/d of low-sulfur diesel. Addition of the hydrogen plant would allow the facility to process heavy sulfur-rich crude oil, which would likely increase overall sulfur production (Sulphur, 2018b).

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for 7% of total domestic production of sulfur in all forms and was the equivalent of 657,000 t of elemental sulfur. Byproduct sulfuric acid production increased by 17% compared with that in 2017 (tables 1, 4). Three sulfuric acid plants operated in conjunction with copper smelters, and two were byproduct operations of lead, molybdenum, and zinc smelting and roasting operations. The three largest byproduct sulfuric acid plants, in terms of size and capacity, were associated with copper smelters and accounted for 85% of domestic byproduct sulfuric acid output. The copper producers—ASARCO LLC, Rio Tinto Kennecott Corp., and Freeport-McMoRan Copper & Gold Inc.—each operated a sulfuric acid plant at its primary copper smelter.

Consumption

Apparent domestic consumption of sulfur in all forms was 3% more than that in 2017 (table 5). Of the sulfur consumed, 69% was obtained from domestic sources as elemental sulfur (64%) and byproduct acid (5%) compared with 72% in 2017, 73% in 2016, 69% in 2015, and 69% in 2014. The remaining 31% was supplied by imports of recovered elemental sulfur (21%) and sulfuric acid (10%) (table 6). The USGS collected end-use data on sulfur and sulfuric acid according to the Standard Industrial Classification of industrial activities.

Sulfur differs from most other major mineral commodities in that its primary use is as a chemical reagent rather than as a component of a finished product. This use generally requires that it be converted to an intermediate chemical product prior to its initial use by industry. The leading sulfur end use, sulfuric acid, represented 68% of reported consumption with an identified end use. Although some sulfur is reported as "elemental sulfur" in table 6, it is reasonable to assume that nearly all the sulfur consumption reportedly used in petroleum refining was first converted to sulfuric acid, bringing sulfur used to produce sulfuric acid to 91% of the total sulfur consumption. Some identified sulfur end uses were included in the "Unidentified" category of table 6 because these data were proprietary. A significant portion of the sulfur in the "Unidentified" category may have been shipped to sulfuric acid producers or exported, although data to support such assumptions were not available.

Because of its many uses, sulfuric acid retained its position as the most universally used mineral acid. Data based on USGS surveys of sulfur and sulfuric acid producers showed that reported U.S. consumption of sulfur for sulfuric acid increased slightly, and total reported sulfur consumption decreased slightly. Reported consumption figures do not correlate with calculated apparent consumption owing to reporting errors and possible double counting in some data categories. These data are considered independently from apparent consumption as an indication of market shares rather than actual consumption totals (table 6).

Agriculture (fertilizers and other agricultural chemicals) was the leading sulfur-consuming industry in 2018; consumption in this end use was about 6.3 Mt, which was slightly more than that in 2017 (table 6). On the basis of export data reported by the

U.S. Census Bureau (undated), the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers decreased by 10% to 2.0 Mt. In 2018, approximately 50% of the wet-process phosphoric acid produced was exported in the form of upgraded granular diammonium and monoammonium phosphate fertilizer and merchant-grade phosphoric acid.

In July 2018, Nutrien Ltd. announced that it would close its Geismar, LA, phosphate production facility by yearend 2018. When operating at capacity, the facility was estimated to consume 300,000 t/yr of sulfuric acid (Acuity Commodities, 2018).

The second-ranked end use for sulfur was in petroleum refining and other petroleum and coal products. Producers of sulfur and sulfuric acid reported that the consumption of sulfur in that end use increased by 5% from that in 2017 (table 6). Consumption of sulfuric acid in copper ore leaching, which was the third-ranked end use, increased by 16% (table 6).

Two types of companies recycle spent and contaminated sulfuric acid from petroleum alkylation—companies that produce acid for consumption in their own operations and then recycle their own spent acid, and companies that provide acid regeneration services to sulfuric acid users. The petroleum-refining industry was thought to be the leading source and consumer of recycled acid for use in its alkylation process, but insufficient data were available to make reasonable estimates.

Stocks

Yearend inventories of recovered elemental sulfur held by domestic producers decreased to 122,000 t, slightly lower than those in 2017 (table 1). On the basis of apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 4-day supply, which was the same as that in 2017. Final stocks in 2018 represented about 2% of the quantity held in inventories at the end of 1976, when sulfur stocks peaked at 5.65 Mt, a 7.4-month supply at that time (Shelton, 1980, p. 877). When the United States mined large quantities of sulfur, as in 1976, mining companies had the capacity to store large quantities. When mining of sulfur ceased in 2000, storage capacity declined significantly. Since that time, stocks have been relatively low because recovered sulfur producers have minimal storage capacity.

Prices

The unit value of sulfur produced in the United States was higher in 2018 than in 2017, as a result of higher 2018 international sulfur prices owing to regional low sulfur supplies from maintenance or weather outages, lower sulfur petroleum processed at refineries, and issues with the ability to transport the sulfur (Sulphur, 2018c). On the basis of value data reported to the USGS, the average unit value of shipments for all elemental sulfur was estimated to be $81.20 per metric ton, which was 75% more than that in 2017 (table 1). The increased unit value reported by producers was higher than the trends in prices recorded in trade publications, which indicated a 55% increase in prices.

Contract prices for elemental sulfur at terminals in Tampa, FL, which were reported weekly in Green Markets, began the year at $110 per long ton. By early October, prices increased to $140 per long ton and remained at this price through yearend.

Prices vary greatly on a regional basis. Prices in Tampa, FL, usually were the highest reported in the United States because of the large demand for sulfur in the central Florida area. At yearend, U.S. west coast prices ranged from $120 per long ton to $130 per long ton. Nearly all the sulfur produced in some regions, such as the west coast, was processed at forming plants, incurring substantial costs to make solid sulfur in acceptable forms to be shipped overseas. The majority of west coast sulfur was shipped overseas.

World sulfur prices generally were higher than domestic prices in 2018. Although prices vary by location, provider, and type, the Abu Dhabi National Oil Co. (ADNOC) price is recognized as an indicator of world sulfur price trends. In 2018, the ADNOC contract price averaged about $147 per metric ton, with the lowest price of $125 per metric ton in May and the highest price of $173 per metric ton in October and November (Fertilizer Week, 2019).

Foreign Trade

Elemental sulfur exports from the United States were 2.4 Mt. The average unit value of exported elemental sulfur was $125 per metric ton, a 17% increase from $107 per metric ton in 2017 (table 7). The leading destination for United States elemental sulfur was Mexico, followed by, in descending order of quantity, Brazil, Morocco, China, Canada, and New Caledonia. Export facilities on the U.S. gulf coast, which began shipping in 2006, have become significant outlets for exported sulfur. Exports from the gulf coast were 1.43 Mt, or 60% of the U.S. total. Exports from the west coast were 968,000 t, or 40% of total U.S. exports (table 1).

In 2018, the United States imported 2.2 Mt of elemental sulfur (table 9). Recovered elemental sulfur from Canada delivered to United States terminals and consumers in the liquid phase furnished 68% of United States sulfur import requirements. Total elemental sulfur imports in 2018 were 20% higher than those in 2017, and higher prices for imported material resulted in the value increasing by 86% compared with that in 2017. Imports from Canada, mostly by rail, were 10% higher than those in 2017 (table 9).

In addition to elemental sulfur, the United States imports and exports sulfuric acid. Sulfuric acid exports of 342,000 t were 39% higher than those in2017 (table 8). Sulfuric acid imports at about 3.0 Mt were about nine times greater than exports (tables 1, 10). Canada and Mexico were the leading sources of sulfuric acid imported into the United States, accounting for 78%, most of which was thought to be byproduct acid from nonferrous metal smelters. Shipments from Canada and some from Mexico came by rail, and the remaining imports came by ship, primarily from Asia and Europe. The tonnage of sulfuric acid imports increased 5% compared to that in 2017, and the value of imported sulfuric acid increased by 37%.

World Review

Of the 14 countries listed in table 11 that produced more than 1 Mt of sulfur, 12 obtained the majority of their production as recovered elemental sulfur. These 14 countries produced 88% of the total sulfur produced worldwide.

The world sulfur industry was composed of two sectors—discretionary and nondiscretionary. In the discretionary sector, the mining of sulfur or pyrites is the sole objective; this voluntary production of either sulfur or pyrites (mostly naturally occurring iron sulfide) is based on the mining of discrete deposits, with the objective of obtaining as nearly a complete recovery of the resource as economic conditions permit. In the nondiscretionary sector, sulfur or sulfuric acid is recovered as an involuntary byproduct; the quantity of output is subject to demand for the primary product and environmental regulations that limit atmospheric emissions of sulfur compounds irrespective of sulfur demand. Discretionary sources (Frasch, native, and pyrites), once the primary sources of sulfur in all forms, represented only 8% of the sulfur produced worldwide in 2018 (table 11).

The Frasch process is the term for hot-water mining of native sulfur associated with the caprock of salt domes and in sedimentary deposits; in this mining method, the native sulfur is melted underground with superheated water and brought to the surface by compressed air. The United States, where the Frasch process was developed early in the 20th century, was the leading producer of Frasch sulfur until 2000. Poland, with 660,000 t, was the only country that produced more than 300,000 t of native sulfur by using either the Frasch process or conventional mining methods (table 11). Small quantities of native sulfur were produced in Asia, Europe, and South America. The importance of pyrites to the world sulfur supply has significantly decreased; China and Finland were the top producers of sulfur from pyrites with China accounting for 86% of the world pyrite production.

Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was estimated to be about the same as that in 2017. Recovered elemental sulfur production and byproduct from metallurgy was slightly higher than that in 2017. Globally, production of sulfur from pyrites was estimated to have been the same as that in 2017. Pyrites is a less attractive alternative to elemental sulfur for sulfuric acid production, primarily because the environmental remediation cost of mining pyrites is high.

Canada.—Ranked fifth in the world in sulfur production, Canada was one of the leading sulfur and sulfuric acid exporters. In 2018, sulfur production, in all forms, in Canada was slightly lower than that in 2017 (table 11). About 80% of Canada's sulfur was recovered at natural gas and oil sands operations in Alberta; some sulfur was recovered from oil sands operations in Saskatchewan, petroleum refineries in other parts of the country, and as byproduct sulfuric acid from metallurgy. Canada's sulfur production was expected to remain stable over the medium term and may increase during the long term as a result of expanded oil sands production.

Environment and Climate Change Canada (2019) published information on Canada's sulfur emissions in 2017, which indicated a 9% decrease from those in 2016 and a 69% decrease from those in 1990. Sulfur emissions in Canada have declined as the result of improved sulfur recovery technology at nonferrous metal smelters but also as a result of reduced emissions from coal-fired, electric-power-generating utilities and plant closures, as well as a reduction in emissions from the petroleum-refining sector. Further decreases in sulfur emissions were achieved through the implementation of low-sulfur fuel standards.

China.—China was the leading global producer of sulfur in all forms and the leading producer of pyrites, with about 25% of its sulfur in all forms coming from that source (table 11). The country was the leading sulfur importer with a total of about 11 Mt, which was about one-third of global trade. Imports represented 55% to 60% of elemental sulfur consumption in China, the bulk of which was used to manufacture sulfuric acid (Sulphur, 2018a).

China's Ministry of Transport announced the expansion of its coastal Emission Control Areas to encompass China's entire coastline. Beginning January 1, 2020, all large vessels would be required to burn bunker fuels with 0.5% sulfur content and smaller vessels would be required to use bunker fuels with 10 parts per million sulfur when the vessels were inland waterways. The policy also required seagoing vessels to use bunker fuels with 0.1% sulfur when entering inland waterway areas in China. (Sulphur, 2019a).

Outlook

Worldwide recovered sulfur output is expected to increase as a result of higher sulfur recovery in the oil and gas sector. New sulfur supplies would mostly come from Kuwait, India, and Saudi Arabia. Through 2015, worldwide production of sulfur was nearly equal to consumption; however, in 2016 sulfur was in surplus. In 2017 and 2018, sulfur production was not enough to meet demand because of project delays and production declines at existing facilities (Prud'homme, 2018, p. 54).

Since 2000, recovered sulfur production in the United States has been relatively stable, averaging about 8.7 million metric tons per year. Production from natural gas operations is expected to increase from that in 2018 as more natural gas is recovered from shale formations as improved technologies reduce natural gas production costs (U.S. Energy Information Administration, 2019a, p. 78).

Domestic byproduct sulfuric acid production may fluctuate somewhat as the copper industry reacts to market conditions and varying prices by adjusting output at operating smelters. Worldwide, the outlook for byproduct acid is more predictable. Because copper production costs in some countries are lower than those in the United States, acid production from those countries has increased, and continued increases are likely. Many copper producers have installed more efficient sulfuric acid plants to limit sulfur dioxide emissions at new and existing smelters. Worldwide, sulfur emissions at nonferrous smelters declined as a result of improved sulfur recovery; increased byproduct acid production is likely to become more a function of metal demand than a function of improved recovery technology. Byproduct sulfuric acid production in the United States has decreased by 36% since 2000. China's smelter acid production has nearly doubled in the past 10 years; however, the rate of increase had begun to slow. China has invested in new copper smelter capacity, which is likely to result in increased sulfuric acid production. China now represents 40% of copper smelter production worldwide (Sulphur, 2019b).

Frasch sulfur and pyrites production, however, are unlikely to have significant long-term increases. Because of the continued increases in elemental sulfur recovery and byproduct sulfuric acid production for environmental reasons, discretionary sulfur has become increasingly less important as demonstrated by the lack of expansion in the Frasch sulfur industry. The Frasch process has become the high-cost process for elemental sulfur production, and any new projects would require sulfur prices to increase enough to justify the initial investment. Pyrites, with significant direct production costs, are an even higher cost raw material for sulfuric acid production when the environmental aspects are considered. Discretionary sulfur output is likely to decline. The decrease likely will be pronounced when large operations are closed for economic reasons, as was the case in 2000 and 2001.

For the long term, sulfur and sulfuric acid likely will continue to be important in agricultural and industrial applications. Phosphate processing, mainly for agricultural uses, continues to be the dominant use of sulfuric acid (about 60%). Phosphate fertilizer is expected to remain a leading end use because the global demand for fertilizer remains strong. Ore leaching (about 10%) likely will be the largest area of sulfur consumption growth. Copper and nickel leaching are major consumers of sulfuric acid; however, high costs and technical difficulties in the high-pressure acid leach process for nickel may result in the use of less expensive options. In addition, uses of sulfuric acid are expanding in other industrial applications such as titanium dioxide pigment production in China and Europe and, caprolactam (used in the production of nylon 6 fibers) manufacturing (Sulphur, 2018d).

References Cited

Acuity Commodities, 2018, Nutrien to stop consuming sulfuric acid at Geismar: Acuity Commodities, Acuity news & info, July 5. (Accessed March 26, 2020, via https://www.acuitycommodities.com.)

Bureau of Safety and Environmental Enforcement, 2018, BSEE reports Hurricane Michael activity statistics—Oct. 11, 2018: Washington, DC, Bureau of Safety and Environmental Enforcement, October 11. (Accessed November 19, 2019, at https://www.bsee.gov/newsroom/latest-news/statements-and-releases/press-releases/bsee-reports-hurricane-michael-22.)

Environment and Climate Change Canada, 2019, Air pollutant emissions: Gatineau, Quebec, Canada, Environment and Climate Change Canada, July 31. (Accessed December 5, 2019, at https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-pollutant-emissions.html.)

Fertilizer Week, 2019, Fertilizer Week historical prices January 3, 2019: Fertilizer Week, January 3. (Accessed March 31, 2020, via https://www.crugroup.com/prices/fertilizers/?term=sulphur.)

International Maritime Organization, 2018, Implementation of Sulphur 2020 limit—Carriage ban adopted: International Maritime Organization press briefing, October 26. (Accessed March 31, 2020, at http://www.imo.org/en/MediaCentre/PressBriefings/Pages/19-Implementation-of-sulphur-2020-limit-.aspx.)

Oil & Gas Journal, 2018, 2018 worldwide refining capacity summary: Oil & Gas Journal, 2 p. (Accessed November 19, 2019, via http://www.ogj.com/ogj-survey-downloads.html.)

Oil & Gas Journal, 2019, Worldwide, U.S. refinery survey—Capacities as of Jan. 1, 2019: Oil & Gas Journal, 24 p. (Accessed November 18, 2019, via https://www.ogj.com/ogj-survey-downloads/worldwide-refining.)

Prud’homme, Michel, 2018, Medium-term outlook for fertilizers and raw materials global supply 2018–2022: Paris, France, International Fertilizer Association Annual Conference, Berlin, Germany, June 18–20, 70 p. (Accessed March 31, 2020, via https://www.fertilizer.org.)

Shelton, J.E., 1980, Sulfur and pyrites, *in* Metals and minerals: U.S. Bureau of Mines Minerals Yearbook 1978–79, v. I, p. 877–897.

Sulphur, 2018a, China’s sulphur import consortium: Sulphur, no. 377, July–August, p. 20–22.

Sulphur, 2018b, Delaware City looks to process more sulphur: Sulphur, no. 378, September–October, p. 14.

Sulphur, 2018c, Market insight–Sulphur: Sulphur, no. 378, September–October, p. 6.

Sulphur, 2018d, Sulphur surplus continues–for now: Sulphur, no. 379, November–December, p. 24–27.

Sulphur, 2019a, China–New sulphur limits on shipping boost low sulphur fuel demand: Sulphur, no. 380, January–February, p. 10.

Sulphur, 2019b, Copper market to boost acid production: Sulphur, no. 380, January–February, p. 24–26.

U.S. Census Bureau, [undated], USA Trade® Online: U.S. Census Bureau. (Accessed April 1, 2020, at https://usatrade.census.gov/.)

U.S. Energy Information Administration, 2019a, Annual energy outlook 2019 with projections to 2050: U.S. Energy Information Administration, January 24, 163 p. (Accessed April 1, 2020, at https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf.)

U.S. Energy Information Administration, 2019b, Refinery utilization and capacity: U.S. Energy Information Administration, July. (Accessed August 28, 2019, at http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.

Sulfur. Ch. in Mineral Commodity Summaries, annual.

Sulfur. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Sulfur. Mineral Industry Surveys, monthly.

Other

Acuity Commodities, biweekly.

Chemical and Engineering News, weekly.

Chemical Engineering, weekly.

Fertilizer International, bimonthly.

Fertilizer Week, weekly.

Green Markets, weekly.

ICIS North America Sulphur Review, monthly.

Industrial Minerals, monthly.

Oil & Gas Journal, weekly.

Sulfur. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

Sulphur, bimonthly.

TABLE 1
SALIENT SULFUR STATISTICS[1]

(Thousand metric tons, sulfur content, and thousand dollars unless otherwise specified)

	2014	2015	2016	2017	2018
United States:					
Quantity:					
Production:					
Recovered	9,050	8,890	9,070	9,070	9,000
Other	587	646	673	560 [r]	657
Total	9,630	9,540	9,740	9,630 [r]	9,660
Shipments:					
Recovered	9,080	8,910	9,080	9,120	9,020
Other	587	646	673	560 [r]	657
Total	9,670	9,560	9,750	9,680 [r]	9,680
Exports:					
Elemental	2,010	1,850 [r]	2,060	2,340	2,390
Sulfuric acid	53	58	59	80 [r]	112
Imports:					
Elemental[e]	2,370	2,240	1,810 [r]	1,850	2,230
Sulfuric acid	1,000	1,160	1,050	954	997
Consumption, all forms[2]	11,000	11,100	10,500	10,100	10,400
Stocks, December 31, producer, recovered	141	138	144	124	122
Value:					
Shipments, free on board (f.o.b.) mine or plant:					
Recovered[e]	734,000	781,000	344,000	423,000	732,000
Other	92,100	75,500	64,800	62,500	88,000
Total	826,000	857,000	409,000	486,000	820,000
Exports, elemental	315,000	284,000	214,000	251,000 [r]	299,000
Imports, elemental	134,000	142,000 [r]	81,700 [r]	110,000 [r]	205,000
Price, elemental, f.o.b. mine or plant[e] dollars per metric ton	80.10	87.60	37.90	46.40 [r]	81.20
World, production, all forms (including pyrites)	77,900 [r]	77,800 [r]	78,900 [r]	79,700 [r]	79,400

[e]Estimated. [r]Revised.
[1]Table includes data available through April 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Calculated as shipments minus exports plus imports.

TABLE 2
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE[1]

(Thousand metric tons and thousand dollars)

	2017			2018		
		Shipments			Shipments	
State	Production	Quantity	Value[e]	Production	Quantity	Value[e]
Alabama	139	140	9,510	136	135	13,200
California	1,160	1,160	51,600	1,210	1,210	92,000
Illinois	557	555	18,500	587	589	41,400
Louisiana	1,590	1,590	83,400	1,540	1,540	133,000
Ohio	154	154	6,500	132	132	9,030
Texas	3,380	3,380	186,000	3,380	3,390	341,000
Washington	156	156	4,760	158	159	6,850
Wyoming	543	548	12,700	509	511	15,900
Other[2]	1,390	1,440	50,000	1,340	1,360	80,300
Total	9,070	9,120	423,000	9,000	9,020	732,000

[e]Estimated.
[1]Table includes data available through April 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes Colorado, Delaware, Florida, Indiana, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Montana, New Jersey, New Mexico, North Dakota, Oklahoma, Pennsylvania, Tennessee, Utah, and Wisconsin.

TABLE 3
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES,
BY PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICT[1]

(Thousand metric tons)

	2017		2018	
District and source	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	216	217	241	240
Natural gas	13	13	13	13
Total	230	231	254	253
PAD 2:				
Petroleum and coke	1,400	1,400	1,340	1,340
Natural gas	7	6	6	6
Total	1,410	1,400	1,340	1,350
PAD 3:				
Petroleum and coke	5,300	5,320	5,280	5,280
Natural gas	146	146	127	126
Total	5,450	5,460	5,410	5,410
PAD 4 and PAD 5:				
Petroleum and coke	1,490	1,520	1,520	1,530
Natural gas	496	501	473	476
Total	1,990	2,020	2,000	2,010
Grand total	9,070	9,120	9,000	9,020
Of which:				
Petroleum and coke	8,410	8,450	8,380	8,400
Natural gas	662	666	619	621

[1]Table includes data available through April 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
BYPRODUCT SULFURIC ACID PRODUCED IN THE UNITED STATES[1]

(Thousand metric tons, sulfur content, and thousand dollars)

Type of plant	2017	2018
Copper[2]	489	586
Zinc, lead, and molybdenum	71 r	71
Total:		
Quantity	560 r	657
Value	62,500	88,000

[r]Revised.
[1]Table includes data available through April 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Excludes acid made from pyrites concentrates.

TABLE 5
CONSUMPTION OF SULFUR IN THE UNITED STATES BY TYPE[1]

(Thousand metric tons, sulfur content)

Type	2017	2018
Elemental sulfur:		
Shipments	9,120	9,020
Exports	2,340	2,390
Imports	1,850 e	2,230
Total	8,630 e	8,860
Byproduct sulfuric acid:		
Shipments	560 r	657
Exports[2]	80 r	112
Imports[2]	954	997
Total	1,430 r	1,540
Grand total	10,100 e	10,400

eEstimated. rRevised.
[1]Table includes data available through April 23, 2020. Crude sulfur or sulfur content. Data are rounded to no more than three significant digits; may not add to totals shown. Consumption is calculated as shipments minus exports plus imports.
[2]May include sulfuric acid other than byproduct.

TABLE 6
SULFUR AND SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE[1]

(Thousand metric tons, sulfur content)

		Elemental sulfur[3]		Sulfuric acid (sulfur equivalent)		Total	
SIC[2] code	End use	2017	2018	2017	2018	2017	2018
102	Copper ores	--	--	239	278	239	278
1094	Uranium and vanadium ores	--	--	2	1	2	1
10	Other ores	--	--	65 r	93	65 r	93
26, 261	Pulp mills and paper products	W	W	125	139	125	139
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals; other chemical products[4]	W	W	90	107	90	107
281	Other inorganic chemicals	W	W	61	67	61	67
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	7	12	7	12
284	Soaps and detergents	--	--	5	5	5	5
286	Industrial organic chemicals	--	--	14	12	14	12
2873	Nitrogenous fertilizers	--	--	305	311	305	311
2874	Phosphatic fertilizers	--	--	5,010	5,070	5,010	5,070
2879	Pesticides	--	--	11	16	11	16
287	Other agricultural chemicals	911	877	22	22	933	899
2892	Explosives	--	--	8	8	8	8
2899	Water-treating compounds	--	--	31	51	31	51
28	Other chemical products	--	--	76	93	76	93
29, 291	Petroleum refining and other petroleum and coal products	2,180	2,300	347	338	2,520	2,640
331	Steel pickling	--	--	11	11	11	11
3691	Storage batteries (acid)	--	--	21	21	21	21
	Exported sulfuric acid	--	--	72	72	72	72
	Total identified	3,090	3,180	6,520	6,730	9,610	9,910
	Unidentified	2,350	2,190	128 r	63	2,130 r	1,910
	Grand total	5,440	5,370	6,650	6,790	11,700 r	11,800

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Unidentified." -- Zero.
[1]Table includes data available through April 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Standard Industrial Classification.
[3]Does not include elemental sulfur used for production of sulfuric acid.
[4]No elemental sulfur was used in inorganic pigments, paints, and allied products.

TABLE 7

U.S. EXPORTS OF ELEMENTAL SULFUR, BY COUNTRY OR LOCALITY[1]

(Thousand metric tons and thousand dollars)

	2017		2018	
Country or locality	Quantity	Value	Quantity	Value
Brazil	710	72,800 r	650	88,400
Canada	211	8,810 r	154	9,400
China	328	50,800	254	32,200
Mexico	464	45,000	686	96,300
Morocco	346	32,000	334	39,000
New Caledonia	106	8,730	102	11,700
Other	178	32,700	214	22,200
Total	2,340	251,000 r	2,390	299,000

rRevised.

[1]Table includes data available through April 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 8

U.S. EXPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY OR LOCALITY[1]

	2017		2018	
Country or locality	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	133,000	$11,800	154,000	$14,200
Chile	19,100	1,750	--	--
Colombia	16	13	11,300	45
Ireland	7,100	9,360	7,620	10,100
Israel	3,010	4,110	2,500	3,270
Jamaica	4,320	276	8,200	541
Korea, Republic of	4,670	310	3,600	284
Mexico	54,300	1,170	58,500	1,130
Saudi Arabia	3,320	49	5,940	369
Singapore	52	101	3,140	167
Suriname	15,900	575	17,000	1,250
Taiwan	125	157	6,950	405
Venezuela	3 r	6 r	59,400	7,410
Other	1,210 r	1,220 r	3,860	1,220
Total	246,000 r	30,900 r	342,000	40,400

rRevised. -- Zero.

[1]Table includes data available through April 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS OF ELEMENTAL SULFUR, BY COUNTRY OR LOCALITY[1]

(Thousand metric tons and thousand dollars)

Country or locality	2017 Quantity	2017 Value[2]	2018 Quantity	2018 Value[2]
Canada	1,380	49,600	1,510	90,600
Mexico	15	753	(3)	11
Other	461	59,700 r	722	115,000
Total	1,850	110,000 r	2,230	205,000

rRevised.
[1]Table includes data available through April 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Declared customs valuation.
[3]Less than ½ unit.

Sources: U.S. Census Bureau and Independent Commodity Intelligence Services PentaSul North American Sulphur Service; data adjusted by the U.S. Geological Survey.

TABLE 10
U.S. IMPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY OR LOCALITY[1]

Country or locality	2017 Quantity (metric tons)	2017 Value[2] (thousands)	2018 Quantity (metric tons)	2018 Value[2] (thousands)
Algeria	819	$316	1,830	$1,010
Belgium	19,000	286	80	13
Canada	1,890,000	80,700	1,900,000	88,100
China	72	53	1,570	226
Colombia	1,050	341	3,040	680
Finland	106,000	3,780	46,600	2,680
Germany	169,000	2,870	221,000	11,200
Iraq	11,800	4,080	4,610	1,990
Japan	2	3	2,460	343
Libya	759	300	1,680	834
Mexico	518,000	14,100	470,000	18,400
Russia	--	--	2,550	1,190
Saudi Arabia	24,200	8,430	39,800	19,400
Spain	113,000	2,660	238,000	12,300
Sweden	55,100	2,110	104,000	5,400
Taiwan	3,810	2,960	6,540	5,110
Other	1,980 r	1,400 r	2,060	1,410
Total	2,920,000	124,000 r	3,050,000	170,000

rRevised. -- Zero.
[1]Table includes data available through April 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Declared cost, insurance, and freight paid by shipper valuation.

Source: U.S. Census Bureau.

TABLE 11

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY OR LOCALITY AND SOURCE[1, 2]

(Thousand metric tons, sulfur content)

Country or locality	2014	2015	2016	2017	2018
Australia, byproduct:					
Metallurgy[e]	810	810	810	810	810
Petroleum	90 [e]	90 [e]	90	90 [e]	90 [e]
Total	900 [e]	900 [e]	900 [e]	900 [e]	900 [e]
Belgium, all forms and sources, unspecified	400 [e]	400 [e]	455	453	453 [e]
Brazil, byproduct:					
Metallurgy	287	259 [r]	260 [r, e]	260 [r, e]	260 [e]
Petroleum	240	236 [r]	240 [e]	240 [e]	240 [e]
Total	527	495 [r]	500 [r, e]	500 [r, e]	500 [e]
Canada, byproduct:					
Metallurgy	590	558	635	524 [r]	532
Petroleum	5,252	5,187	4,746	4,803 [r]	4,792
Total	5,842 [r]	5,745 [r]	5,381 [r]	5,327 [r]	5,324
Chile, byproduct, metallurgy	1,514 [r]	1,488 [r]	1,596 [r]	1,524 [r]	1,500 [e]
China:					
Byproduct:					
Metallurgy[e]	7,500	7,400	7,100	7,100	7,100
Natural gas and petroleum	5,800	5,530	5,500	5,940	5,900 [e]
Pyrites	5,150	4,360	4,400 [e]	4,400 [e]	4,400 [e]
Total	18,450 [r]	17,290 [r]	17,000	17,440 [r]	17,400 [e]
Finland:					
Byproduct:					
Metallurgy	336	336	340	340 [e]	340 [e]
Petroleum	130 [e]	130 [e]	130	130 [e]	130 [e]
Pyrites	353 [e]	556	384	470	470 [e]
Total	819	1,022 [r]	854	940	940 [e]
France, byproduct, natural gas and petroleum	400 [e]	400 [e]	400	400 [e]	400 [e]
Germany, byproduct:					
Metallurgy	438	384	352	328 [r]	330 [e]
Natural gas and petroleum	708	628	578	538	538 [e]
Total	1,146 [r]	1,012 [r]	930	866 [r]	868 [e]
India, byproduct:					
Metallurgy	1,200 [e]	1,200 [e]	1,200	1,200	1,200 [e]
Petroleum	1,901 [r]	1,928 [r]	2,009 [r]	2,227 [r]	2,230 [e]
Total	3,101 [r]	3,128	3,209 [r]	3,427 [r]	3,430 [e]
Iran, byproduct, natural gas and petroleum[e]	2,100 [r]	2,200	2,200	2,200	2,200
Italy, byproduct:					
Metallurgy	40 [r]	40 [r]	40 [r]	40 [r, e]	40 [e]
Petroleum[e]	510	510	510	510	510
Total	550 [r]	550 [r]	550 [r]	550 [r]	550 [e]
Japan, byproduct:					
Metallurgy	1,691 [r]	1,629 [r]	1,700 [r]	1,700 [e]	1,700 [e]
Petroleum	1,751	1,733	1,818	1,789	1,697
Total	3,442 [r]	3,362 [r]	3,518 [r]	3,489 [r]	3,397
Kazakhstan, byproduct:					
Metallurgy[e]	604	604	604	604	604
Natural gas and petroleum	2,465	2,520 [e]	2,547	2,914	2,910 [e]
Total	3,069 [r]	3,120 [e]	3,151 [r]	3,518 [r]	3,510 [e]
Korea, Republic of, byproduct:					
Metallurgy	1,080 [e]	1,080 [e]	1,078	1,080 [r, e]	1,080 [e]
Natural gas and petroleum	1,200	1,450	2,000	2,000	2,000 [e]
Total	2,280 [r]	2,530	3,078 [r]	3,080	3,080 [e]
Kuwait, byproduct, petroleum	850	850	850	850 [e]	850 [e]
Mexico, byproduct, natural gas and petroleum	993	858	673	551	447

See footnotes at end of table.

TABLE 11—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY OR LOCALITY AND SOURCE[1, 2]

(Thousand metric tons, sulfur content)

Country or locality	2014	2015	2016	2017	2018
Netherlands, byproduct:[e]					
Metallurgy	120	120	120	120	120
Petroleum	410	400	400	400	400
Total	530	520	520	520	520
Poland:					
Byproduct: [3]					
Metallurgy[e]	260	280	280	280	280
Natural gas	24	24	25	23 r	23 e
Petroleum[e]	269	269	269	269	269
All forms and sources, unspecified	1	1	1	1 e	1 e
Frasch[3]	605	628	621	663	660 e
Total	1,159 r	1,202 r	1,196 r	1,236 r	1,230 e
Qatar, byproduct, natural gas	2,136	2,377 r	2,419 r	2,000 r	2,000 e
Russia:					
Byproduct:					
Metallurgy[e]	200	200	200	200	200
Natural gas	5,859	5,961	6,097	6,100 e	6,100 e
Petroleum[e]	500	500	500	500	500
Native	119 e	110	94	96	96 e
Pyrites[e]	180	180	180	180	180
Total	6,858 r	6,951 r	7,071 r	7,076 r	7,080 e
Saudi Arabia, all forms and sources, unspecified	4,400	4,900	6,000	6,500 r	6,500 e
Turkmenistan, byproduct, all forms and sources, unspecified	506	600	400 r	200 r	200 e
United Arab Emirates, byproduct, natural gas and petroleum[e]	3,300	3,300	3,300	3,300	3,300
United States, byproduct:					
Metallurgy	587	646	673	560 r	657
Natural gas	1,000	982	781	662	619
Petroleum	8,040	7,910	8,290	8,410	8,380
Total	9,630	9,540	9,740	9,630 r	9,650
Uzbekistan, byproduct:[e]					
Metallurgy	131	125 r	130	130	130
Natural gas and petroleum	340	340	350 r	340	340
Total	471	465 r	480 r	470	470
Venezuela, byproduct, natural gas and petroleum	700	700	700 e	700 e	700 e
Other (total):[4]					
Byproduct:					
Metallurgy	399	340 r	344 r	491 r	484
Natural gas and petroleum	415	430	429	410 r	407
Petroleum	456 r	515 r	558 r	567 r	561
All forms and sources, unspecified	319 r	315 r	225 r	235 r	231
Frasch, native	218	251 r	256	259	259
Pyrites[e]	40	40	40	40	40
Total	1,847 r	1,891 r	1,852 r	2,002 r	1,982
Grand total	77,900 r	77,800 r	78,900 r	79,700 r	79,400
Of which:					
Byproduct:					
Metallurgy	17,800 r	17,500 r	17,500 r	17,300 r	17,400
Natural gas	9,020	9,340 r	9,320 r	8,790 r	8,750
Natural gas and petroleum	18,400 r	18,400 r	18,700 r	19,300 r	19,100
Petroleum	20,400 r	20,300 r	20,400 r	20,800 r	20,600
All forms and sources, unspecified	5,630 r	6,220 r	7,080 r	7,390 r	7,390
Frasch, native	942	989 r	971	1,020	1,020
Pyrites[e]	5,720	5,140	5,000	5,090	5,090

See footnotes at end of table.

TABLE 11—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY OR LOCALITY AND SOURCE[1, 2]

[e]Estimated. [r]Revised. -- Zero.

[1]Table includes data available through July 22, 2019. All data are reported unless otherwise noted. Grand totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]The term “source” reflects the means of collecting sulfur and the type of raw material. Sources listed include the following: Frasch recovery; native, comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch); pyrites (whether or not the sulfur is recovered in the elemental form or as acid); byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations including associated coal processing, crude oil and natural gas extraction, petroleum refining, oil sand cleaning, and processing of spent oxide from stack-gas scrubbers; and recovery from processing mined gypsum. Recovery of sulfur in the form of sulfuric acid from synthetic gypsum produced as a byproduct of phosphatic fertilizer production is excluded, because to include it would result in double counting. Production of Frasch sulfur, other native sulfur, pyrites-derived sulfur, mined gypsum-derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from oil sands are all credited to the country of origin of the extracted raw materials. In contrast, byproduct recovery from metallurgical operations, petroleum refineries, and spent oxides are credited to the nation where the recovery takes place, which is not the original source of the

[3]Government of Poland sources report total Frasch and native mined elemental sulfur output annually, undifferentiated; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources.

[4]Includes, Algeria, Austria, Bahrain, Colombia, Croatia, Denmark, Egypt, Greece, Hungary, Iraq, Israel, Libya, Lithuania, Morocco, Nigeria, Norway, Oman, Pakistan, South Africa, Taiwan, Turkey, and Ukraine.