2018 Minerals Yearbook

FLUORSPAR [ADVANCE RELEASE]

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Fluorspar

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In 2018, the bulk of fluorspar consumed in the United States was from imports. Although not included in fluorspar production or consumption calculations, byproduct fluorosilicic acid (FSA) from some phosphoric acid producers, byproduct hydrofluoric acid (HF) from the U.S. Department of Energy's (DOE's) conversion of depleted uranium hexafluoride (DUF_6), and small amounts of byproduct synthetic fluorspar produced from industrial waste streams supplemented fluorspar as a domestic source of fluorine. Apparent consumption of fluorspar was 450,000 metric tons (t), 378,000 t of which was acid grade and 71,300 t of which was metallurgical grade. Total apparent consumption increased by 15% compared with 2017. World production increased slightly to 6.72 million metric tons (Mt) (table 1).

Fluorspar is the commercial name that refers to crude or beneficiated material that is mined and (or) milled for the mineral fluorite (calcium fluoride, CaF_2). Although there are no universal specifications, fluorspar with a minimum CaF_2 content of 97% has historically been referred to as acid grade (also called acidspar) because of its primary use in the manufacture of HF. Fluorspar with a CaF_2 content less than 97% has been referred to as metallurgical grade (also called metspar) because of its primary use as a steelmaking flux. These generalized terms were likely reinforced by the Harmonized Tariff Schedule of the United States (HTS), which differentiates only two categories of fluorspar based on CaF_2 content. Specifications for both acidspar and metspar have changed over time, varied by industry and geography, and have trended towards higher CaF_2 content and more stringent specifications on allowable impurities so that, in practice, the distinction between the two has been far less defined than the CaF_2-content designation suggests. In recent years, numerous fluorspar producers have begun to develop and market products specifically for the cement industry. The CaF_2 content of these products was generally 40% to 50%, much lower than the CaF_2 content of metspar typically used as a steelmaking flux.

Legislation and Government Programs

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals, including fluorspar (U.S. Department of the Interior, 2018). This list was developed to serve as an initial focus, pursuant to Executive Order 13817, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals." As defined by the Executive order, a critical mineral is defined as (1) a non-fuel mineral or mineral material essential to the economic and national security of the United States, (2) the supply chain of which is vulnerable to disruption, and (3) that serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for our economy or our national security (Trump, 2017).

The U.S. Environmental Protection Agency's (EPA's) Significant New Alternatives Policy (SNAP) program was established under section 612 of the Clean Air Act Amendments of 1990 for the purpose of meeting the United States' obligations under the Montreal Protocol on Substances that Deplete the Ozone Layer. Because of the ozone-depleting potential of early generations of fluorocarbon gases—chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)—many fluorinated substances used as foam-blowing agents, propellants, refrigerants, and solvents had been identified for reduction and eventual phase out under the SNAP program. In many cases, hydrofluorocarbons (HFCs), which are not ozone-depleting substances, had been approved as acceptable alternatives. In 2015, Mexichem Fluor, Inc. challenged a final rule under the SNAP program that restricted the use of certain HFCs because of their high global warming potential (GWP). In 2017, the D.C. Circuit Court of Appeals ruled that because HFCs are not ozone-depleting substances, the EPA did not have the authority to regulate the use of HFCs under the SNAP program (U.S. Environmental Protection Agency, 2016, undated c; U.S. Court of Appeals for the District of Columbia Circuit, 2017). However, Honeywell International, Inc. and The Chemours Co. filed an appeal arguing that the court ignored the EPA's original directive to replace ozone-depleting substances with safer alternatives (Chemours Co., The, 2017; Honeywell International, Inc., 2017), which the court rejected in January 2018 (Cooling Post, 2018). A few States were considering implementing their own HFC regulations.

Per- and polyfluoroalkyl substances (PFASs) are a class of fluorinated chemicals with a wide range of uses. They are commonly used to make products that are resistant to grease, oil, and water. PFASs have been used in fire-fighting foams and as a processing aid in the manufacture of fluoropolymers. These substances, particularly long-chain PFASs (PFAS molecules containing eight or more carbon atoms, which are sometimes referred to as C-8), have come under scrutiny over the past 15 years owing to their environmental persistence, prevalence in the bloodstream of the human population, and widespread geographic distribution. PFASs may enter the environment directly or through the degradation of other fluorinated telomers.

Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) are two types of long-chain PFASs that have received the most attention. Human studies have examined possible links between elevated blood levels of PFOA and PFOS and numerous adverse health conditions. Domestically, PFOS was voluntarily phased out of production by 2002, and the EPA's voluntary 2010/2015 PFOA Stewardship Program likely reduced or eliminated the manufacture and import of PFOA and other long-chain PFASs. However, numerous communities and States across the United States have identified localized areas with PFOA and PFOS contamination, particularly those near industrial sites where the chemicals were manufactured or used or near airfields where the chemicals were used in firefighting foams (Interstate Technology & Regulatory Council, 2020; U.S. Environmental Protection Agency, undated a).

In March 2018, the U.S. Department of Defense (DOD) briefed the U.S. House of Representatives Armed Services Committee on the status of its investigation into the scope of PFAS contamination at military bases where the military had used aqueous film-forming foam in crash training and fire suppression. The DOD identified at least 126 installations where drinking or groundwater supplies were contaminated with levels of PFOA and (or) PFOS that exceeded the EPA's drinking water health advisory limit. In addition to the characterization and remediation of contaminated water supplies, the DOD continued research and development on fluorine-free firefighting foams (Sullivan, 2018, p. 7, 10, 11).

The Consolidated Appropriations Act of 2018 allocated approximately $100 million for Federal activities related to PFAS contamination. Most of the funding was directed to the U.S. Air Force and the U.S. Navy to address PFAS contamination at military bases around the country, and additional funding was given to the DOD to conduct health screenings related to drinking water contamination. The act also directed the Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry to begin a 5-year nationwide study on the effects of PFAS-contaminated water on human health (Bagenstose, 2018; U.S. Congress, 2018, p. 34b, 43, 44).

In May 2018, the EPA convened a 2-day summit on PFAS that included representatives from across the United States, including all levels of Government, Tribal organizations, industry groups, and nongovernmental organizations. After the conclusion of the summit, the EPA prioritized four actions that it would take to address PFAS contamination including (1) evaluating the need for establishing maximum contaminant levels for PFOA and PFOS, (2) evaluating statutory mechanisms for designating PFOA and PFOS as hazardous substances, (3) issuing groundwater cleanup recommendations for sites contaminated with PFOA and (or) PFOS, and (4) developing toxicity values for other PFAS including ammonium 2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propanoate and hexafluoropropylene oxide dimer acid (known commercially as GenX™ chemicals) and perfluorobutane sulfonic acid (U.S. Environmental Protection Agency, 2018).

Production

In 2018, small amounts of fluorspar may have been produced in Illinois by Hastie Mining & Trucking (Cave-in-Rock, IL) as a byproduct of limestone mining operations, but no data were collected on quantities produced. Synthetic fluorspar may have been produced as a byproduct of petroleum alkylation, stainless-steel pickling, and uranium processing. However, the U.S. Geological Survey (USGS) does not have a data survey for synthetic fluorspar produced in the United States.

In 2018, three companies—J.R. Simplot Co. (Boise, ID), Mosaic Fertilizer LLC (Tampa, FL; a subsidiary of The Mosaic Co.), and Nutrien Ltd. (Saskatoon, Saskatchewan, Canada)—produced marketable FSA, a byproduct from the processing of phosphate rock into phosphoric acid, at five plants in Florida, Louisiana, North Carolina, and Wyoming. Domestic production data for FSA were collected by the USGS from a voluntary canvass of U.S. phosphoric acid operations known to recover FSA. Of the five FSA operations surveyed, responses were received from four, representing 99% of the total FSA sold or used by producers. In 2018, production was 32,500 t (equivalent to about 52,900 t of fluorspar grading 100% CaF_2), an 18% decrease compared with that in 2017 (table 1).

Core Metals Group (Aurora, IN), Hastie Mining & Trucking, and Seaforth Mineral & Ore Co., Inc. (East Liverpool, OH) marketed screened and dried imported acid- and metallurgical-grade fluorspar. Hastie Mining & Trucking also continued development of the Klondike II fluorspar mine in Livingston County, KY.

DOE's DUF_6 conversion project operated two plants—one in Paducah, KY, and the Portsmouth facility in Piketon, OH. The goal of the project, which started production in 2011, was to convert the Government's inventory of DUF_6 into more stable forms, including uranium oxide and aqueous HF. After conversion, the HF was sold in the commercial market. Operations at both plants were suspended in early 2015 owing to the failure of the HF condensers. After replacing the condensers, production resumed in all four lines at the Paducah plant by yearend 2017. In 2018, DOE completed replacement of the condensers at the Portsmouth facility and restarted operations in all three lines. With all seven lines in operation, DOE reported that the project had recovered a total of 45,400 t of aqueous HF (Edwards, 2017, p. 107–126; U.S. Department of Energy, 2018, 2019).

Consumption

Apparent consumption of fluorspar was 450,000 t, a 15% increase compared with 390,000 t in 2017 (table 1). Apparent consumption of acid-grade fluorspar increased by 15% to 378,000 t and that of metallurgical-grade fluorspar increased by 10% to 71,300 t.

In the United States, FSA was used primarily for water fluoridation, but it also was used as a treatment and cleaner for metal surfaces and for pH adjustment in industrial textile processing and laundries. FSA also was used in the processing of animal hides, for hardening masonry and ceramics, and in the manufacture of other chemicals. Internationally, FSA was used as an alternative to fluorspar in the production of aluminum fluoride (AlF_3), accounting for an estimated 11% of global production (Roskill Information Services Ltd., 2020, p. 115). Because of differing physical properties, AlF_3 produced from FSA is not readily substituted for AlF_3 produced from fluorspar. Technology to produce HF from FSA also exists but has only been implemented commercially at a few plants in China. In 2018, the amount of FSA sold or used by producers in the United States was 32,100 t (table 1), an 18% decrease compared with that in 2017 (table 1) and used primarily for water fluoridation.

Globally, there were three leading fluorspar-consuming industries. The manufacture of HF, the leading source of fluorine in industrial applications and a precursor to the production of most other fluorine-containing chemicals, accounted for approximately 47% of global annual fluorspar consumption.

The manufacture of AlF_3 and cryolite (Na_3AlF_6), essential for primary aluminum smelting, accounted for approximately 20% of global annual fluorspar consumption. (Although HF is produced as an intermediate in the manufacture of AlF_3, consumption statistics differentiate the two uses.) These applications typically require acid-grade fluorspar, although FSA also can be used. Fluorspar used as a steelmaking flux accounted for approximately 26% of global consumption, typically in the form of metspar, although acid-grade material also may have been used (Roskill Information Services Ltd., 2020, p. 86). Other applications of fluorspar included use in the manufacture of cement, ceramics, enamel, glass, and welding rod coatings.

Aluminum.—Internationally, acid-grade fluorspar was used in the production of AlF_3 and cryolite, which are essential in primary aluminum smelting. Alumina (Al_2O_3) is dissolved in a bath consisting primarily of molten cryolite and small amounts of AlF_3 and fluorspar to allow electrolytic recovery of aluminum. During the aluminum smelting process, the amount of excess sodium in the bath (a result of impurities in the alumina) is controlled by the addition of AlF_3, which reacts with the sodium to form cryolite. This reaction results in excess bath material, which is drawn off in liquid form, allowed to cool and solidify, and then can be crushed and reused to start new smelter pots or compensate for electrolyte losses. This excess material is variously called crushed tapped bath, secondary cryolite, or bath cryolite. In the aluminum smelting process, AlF_3 is also used to replace fluorine losses (either absorbed by the bath walls or captured as emissions). The AlF_3 requirements of the U.S. aluminum industry were met through imports in 2018 (table 8) as there were no active AlF_3 producers in the United States.

Chemicals.—The United States was a leading producer of HF with a capacity of 220,000 metric tons per year (t/yr) in 2018, second only to China (Roskill Information Services Ltd., 2020, p. 24, 243). HF was used directly in a variety of industrial processes or as an intermediate in the production of organic and inorganic fluorine chemicals. Two companies used fluorspar for the production of HF in 2018—Chemours and Honeywell. Major U.S. producers of downstream fluorochemicals that used HF as an intermediate were Arkema SA, Chemours, Daikin America, Inc., Honeywell, Mexichem Flúor, Inc. (known commercially as Koura), and Solvay Solexis Inc.

In direct use, HF was crucial in many manufacturing processes such as in the cleaning and etching of semiconductors and circuit boards, the enrichment of uranium, the production of low-octane fuels (petroleum alkylation), and the removal of impurities from metals (pickling). HF's primary use, however, was as a chemical intermediate in the production of organic fluorocarbon chemicals, which accounted for approximately 49% of global annual acid-grade fluorspar consumption and an estimated one-third of global annual fluorspar consumption (Roskill Information Services Ltd., 2020, p. 30, 31). Fluorocarbons can be further subdivided into non-feedstock uses (which are typically emissive) and feedstock uses (used captively in the manufacture of other chemicals such as fluoropolymers). This distinction was important because most non-feedstock uses are subject to global regulation under the Montreal Protocol.

Historically, the leading non-feedstock end uses of fluorocarbons have been as aerosols, foam-blowing agents, propellants, and refrigerant gases. Because of the ozone-depleting potential of early generation fluorocarbon gases (CFCs and later HCFCs), many of these substances were targeted for reduction and eventual phase out under the Montreal Protocol, which was adopted in 1987. In order to adapt to evolving regulatory requirements, non-feedstock CFCs and HCFCs were replaced by HFCs. Although not ozone depleting, HFCs (as well as their predecessors) are in many cases potent greenhouse gases owing to high GWP and long atmospheric lifecycles (U.S. Environmental Protection Agency, undated b). The adoption of the Kigali Amendment in 2016 effectively expanded the scope of the Montreal Protocol to phase down the use of many higher GWP HFCs. Although the fluorocarbon market was expected to continue to grow overall, ongoing regulatory mechanisms were expected to constrain growth in non-feedstock applications (Wietlisbach, 2019, p. 19).

Feedstock uses of fluorocarbons, including those used as intermediates in the manufacture of fluoropolymers and fluoroelastomers, have not been restricted by the provisions of the Montreal Protocol because chemicals used entirely as feedstock in the manufacture of other chemicals are excluded from production and consumption calculations. Fluoropolymers and fluoroelastomers are fluorine-containing plastics and rubbers that possess a wide range of advantageous properties including low adhesion; low index of refraction; low gas permeability; and chemical, electrical, oil, temperature, and water resistance, which make them invaluable in a wide range of applications in harsh and demanding environments. According to a report commissioned by the FluoroCouncil, an industry trade group, the United States was a leading producer and net exporter of fluoropolymers in 2018, when combined sales of fluoropolymers and fluoroelastomers were reported to be 85,000 t valued at $2 billion. Because of often unique and specialized performance requirements for fluoropolymers used a in a variety of advanced technology applications, a relatively high percentage of industry revenue (6%) went to ongoing research and development. The electronics sector was the leading consumer of fluoropolymers, accounting for 31% of consumption. Primary applications of fluoropolymers in this sector were in the manufacture of semiconductors, because of their resistance to aggressive etchant chemicals, and in optical and data transmission cables, because of their dielectric properties, fire resistance, high transmission speed, and reliability. Consumption in the electronics sector was followed by the transportation sector (25%) in which fluoropolymers were typically used as fuel lines, hydraulic hoses, wire insulation, and as a variety of gaskets and seals; and in the chemical and industrial processing sector (16%) for corrosion-resistant coatings, linings, piping, vessels, and fluid-handling components. Other important applications included architectural panels, fabrics, and coatings in building and construction; consumer products such as nonstick cookware and waterproof textiles; electrode binder and separator coatings in lithium-ion batteries; films and coatings to protect solar photovoltaics in the energy sector; and as implantable devices such as catheters, grafts, guidewires, ligaments, and pumps in the medical sector (Wood Environment & Infrastructure Solutions UK Ltd., 2020).

Steel and Other Uses.—The fluorspar market in the United States included sales of acid- and metallurgical-grade material mainly to steel mills, where it was used as a fluxing agent to increase slag fluidity. Sales also were made to smaller markets such as cement plants, foundries, glass and ceramics plants, and welding rod manufacturers in railcar, truckload, and smaller quantities. Data on merchant fluorspar sales were withheld in the tables to avoid disclosing company proprietary data. In the late 1970s, the United States used more than 500,000 t/yr for fluxes and other applications. During the past 20 to 30 years, however, fluorspar use in such industries as steel and glass has declined because of product substitutions or changes in industry practices.

Transportation

The United States depends on imports for most of its fluorspar supply. Metallurgical-grade fluorspar was shipped routinely as lump or gravel, with the gravel passing a 75-millimeter (mm) sieve and not more than 10% by weight passing a 9.5-mm sieve. Acid-grade fluorspar was shipped in the form of damp filtercake that contained 7% to 10% moisture to facilitate handling and reduce dust. This moisture was removed by heating the filtercake in rotary kilns or other dryers before treating with sulfuric acid to produce HF. Acid-grade imports were usually shipped by ocean freight using bulk carriers of 10,000- to 50,000-t deadweight capacity; ships in this size range are termed “handymax.” Some of the acid-grade and ceramic-grade fluorspar was marketed in bags for small users and shipped by truck.

Prices

According to Fastmarkets IM (2017, 2019), the yearend price of fluorspar from all leading exporting countries increased in 2018. The yearend price of acid-grade fluorspar from China (free-on-board wet filtercake) was $550 to $580 per metric ton, a 38% increase compared with prices in 2017, and acid-grade fluorspar from South Africa (free-on-board Durban filtercake) more than doubled to $450 to $490 per metric ton. The price of acid-grade fluorspar from Mexico (free-on-board Tampico filtercake) was $400 to $450 per metric ton, a 57% increase compared with prices in 2017, although the 2018 yearend price of acid-grade fluorspar from Mexico presumably included material previously listed as low-arsenic (<5 parts per million) acidspar, which historically sold at a higher price than arsenic-containing acidspar from Mexico. Metallurgical-grade fluorspar from Mexico was $300 to $320 per metric ton, a 29% increase compared with prices in 2017 (table 3).

Despite the price increases, Fastmarkets reported that the 2018 yearend price of acid-grade fluorspar at ports in the Gulf coast including cost, insurance, and freight remained unchanged from that in 2017 at $260 to $270 per metric ton. This was generally consistent with the annual average unit value of acid-grade imports which was $276 per metric ton, a 3% increase compared with that in 2017. The annual average unit value of metallurgical-grade fluorspar was $258 per metric ton, a 9% increase compared with that in 2017. Domestic consumers may have been less affected by price increases elsewhere because fluorspar was purchased using long-term supply contracts and because prices in Mexico, which accounted for 68% of domestic imports (table 5), did not begin to increase until the second half of 2018.

Foreign Trade

In 2018, U.S. exports of fluorspar decreased by 18% to 8,970 t compared with those in 2017 (table 4). With the absence of fluorspar stocks in the National Defense Stockpile and only a small amount of mined or byproduct fluorspar produced, exports were likely reexports of imported material. Approximately 73% of exports went to Canada.

In 2018, combined acid- and metallurgical-grade fluorspar imports for consumption were 459,000 t, a 14% increase compared with those in 2017 (table 5). Acid-grade imports were 381,000 t, a 15% increase compared with those in 2017. Metallurgical-grade imports increased by 10%, to 77,600 t, and 97% were from Mexico. The leading suppliers of acid- and metallurgical-grade fluorspar to the United States were Mexico (68%), Vietnam (16%), South Africa (9%), and Spain (4%).

In 2018, imports of HF were essentially unchanged at 122,000 t (table 6) from that in 2017; most HF imports were from Mexico (92%). Imports of cryolite increased by 70% to 16,800 t, with Japan (45%) and Canada (23%) being the leading suppliers (table 7). AlF_3 imports increased by 24% to 25,600 t (table 8); the leading suppliers of AlF_3 were Mexico (45%), Canada (33%), and China (21%). The increase in cryolite and AlF_3 imports was likely related to a 20% increase in primary aluminum production in 2018 (Bray, 2020).

World Review

Canada.—In August 2018, Canada Fluorspar (NL) Inc. (St. Lawrence, Newfoundland and Labrador) made its first shipment of 4,700 t of acid-grade concentrate from its St. Lawrence Fluorspar project located in the Burin Peninsula of Newfoundland and Labrador. This was the first production from the company’s 200,000-t/yr-capacity flotation mill. The company was ramping up production using ore that had been stockpiled during open pit mine development. Acid-grade imports to the United States in 2018 included 11,000 t from Canada (table 5) (Canada Fluorspar Inc., 2015, p. 9, 27, 28; Telegram, The, 2018).

China.—China is the world’s leading producer and consumer of AlF_3, fluorspar, fluorocarbons (feedstock and non-feedstock), and HF. Throughout the 1990s, China was the leading global fluorspar exporter. However, for the past two decades, Government policy evolved to discourage exports in favor of development of downstream consuming industries and increased vertical integration. In 2017, the Government declared fluorspar to be a strategic mineral and was prioritized for stricter controls on the use of mineral resources, establishment of key targets for financial investment, and increased monitoring to support Government initiatives. In December 2018, the Fluorite Industry Development Association of China was established in Beijing to facilitate development and standardization within the fluorspar industry (Rhode, 2019b, p. 21, 23; Roskill Information Services Ltd., 2020, p. 140, 141).

According to the Ministry of Land and Resources, production of fluorspar in China totaled approximately 4 million metric tons per year from 2014 to 2017, accounting for approximately 60% of total world production in 2018 (table 9). Actual production, however, may have been much higher. The China Nonmetallic Minerals Industry Association (CNMIA) estimated China's fluorspar production, based on Provincial data, to be 6.02 Mt in 2018. The leading Provinces in terms of production quantity were Hunan, Inner Mongolia, Jiangxi, and Zhejiang. The number of operating mines in the country decreased in recent years, from more than 1,200 in 2013 to 251 by yearend 2018. Resources at many of the mid- and large-scale mines were reportedly nearing depletion. In addition to resource depletion, production in 2018 was adversely affected by increased environmental restrictions on the mining industry. These restrictions impacted fluorspar mining, stopping production in several mining localities including Guangde in Anhui Province, Qilianshan in Gansu Province, and Xinyang in Henan Province in 2018 (Liao, 2019).

CNMIA estimated fluorspar consumption to be approximately 6 Mt and likely to increase. Compared with 2017, China's fluorspar consumption for the production of both HF and AlF_3 increased, by 13% and 9%, respectively, to 3.77 Mt and 1.12 Mt. Consumption of metspar (presumably referring to high-grade metallurgical lump) and briquets, both used as steelmaking fluxes, increased by 8% to 810,000 t in 2018. However, the proportion of metspar and briquets shifted from a higher proportion of metspar in 2017 to briquets in 2018. The transition to greater use of briquets may support reports that China's high-grade fluorspar deposits have been progressively depleted. Consumption in other industries such as ceramics, glass and glass fibers, and welding rods decreased slightly to 490,000 t (Liao, 2019).

All of these factors likely contributed to China becoming a net importer of fluorspar in 2018. Although the country continued to be a net exporter of acid-grade fluorspar, this was more than offset by increased imports of metspar, primarily from Mongolia. Although the quantity of net metspar imports was very small (about 100,000 t) compared with consumption (about 6 Mt), the uncertainty with regard to China's production and the prospect of increased competition from China for fluorspar in the global marketplace heightened concerns about global availability.

Kenya.—On April 1, 2018, control of Kenya Fluorspar Co.'s assets in the Kerio Valley reverted to the Government after the company opted not to renew its 20-year lease. Operations at the mine and 100,000-t/yr processing plant were idled in 2016 (Roskill Information Services Ltd., 2018).

Mongolia.—From 2014 to 2017, Mongolia's production of fluorspar ranged between 300,000 and 400,000 t, but in 2018, production was estimated to have increased by 59%, to 605,000 t (table 9). Increased production was attributed to a large increase in China's imports beginning in the second half of the year. Although Mongolia has been known to produce acid-grade fluorspar, many plants produced lower grade flotation concentrate that did not meet the specifications required by most leading acid-grade consumers. The majority of China's imports were reportedly of metallurgical-grade fluorspar; however, some analysts believed that a significant portion may have been used for the production of HF, either directly or after upgrading. Others suggested that China's fluorspar imports from Mongolia were more likely used as metspar, owing to the increasing difficulty of sourcing high-grade metallurgical lump in China.

The Government of Mongolia has encouraged investment in the mining sector to support economic growth. In 2018, the Mineral Resources and Petroleum Authority announced that five new fluorspar projects with completed feasibility studies were expected to be launched in 2019, adding to the approximately 20 fluorspar processing plants that were already in operation (Rhode, 2019b, p. 33–39).

Morocco.—GFL GM Fluorspar SA began production of acid-grade fluorspar from a new mine in Taourirt. The operation was established as a joint venture between Gujarat Fluorochemicals Ltd. (India) and Global Mines sarl (Morocco). Concentrate from the 40,000-t/yr operation would be exported through the Port of Nador, primarily to Gujarat's HF operations in India and fluorochemical producers in Europe (Rhode, 2019a; Gujarat Fluorochemicals Ltd., 2020, p. 47).

South Africa.—Sephaku Flouride Ltd. continued to develop its Nokeng Fluorspar Mine (Nokeng) and milling project in Rust de Winter, Gauteng Province. Nokeng is in the Bushveld Complex directly south of the Minersa Group's Vergenoeg Mine, the country's only operational fluorspar mine. Open pits would be developed at two of three fluorspar-hematite deposits that compose the Nokeng Fluorspar Mine—the Outwash Fan, with an average ore grade of 22.7% CaF_2, and Plattekop, with an average ore grade of 38.2% CaF_2. Construction of the flotation plant, which had a capacity of 180,000 t/yr of acid-grade fluorspar and 30,000 t/yr of metallurgical-grade fluorspar briquets and was designed to accommodate differing types of ore, was completed in October 2018. The estimated mine life was 19 years, and first production was expected in early 2019 (Wagner, 2018, p. 3, 4, 11, 12).

Vietnam.—Nui Phao Mining Co. Ltd. (Masan Resources Corp.) produced 238,702 t of acid-grade fluorspar concentrate from its Nui Phao polymetallic mine in Thai Nguyen Province, a slight increase compared with production in 2017. The company has reported increased production of fluorspar each year since the mine went into operation in 2014, which it attributed to the implementation of successive capital upgrades to increase ore throughput and enhance recovery rates, particularly in the tungsten- and fluorspar-processing circuits. Fluorspar recovery increased by 4% in 2018, despite a 2% decrease in mill feed grades. The company also reported a 29% increase on realized fluorspar pricing in 2018, which it attributed to strong demand from AlF_3 and HF markets, China's increased regulation of its domestic mining and chemical sector, limited availability from new fluorspar suppliers, and sustained strong demand from United States customers (Masan Resources Corp., 2019, p. 22, 24, 75, 78, 79). In 2018, according to U.S. Census Bureau statistics, 19% of domestic acid-grade imports (71,300 t) were from Vietnam (table 5).

Outlook

Because of fluorspar's role as the basic material for almost all fluorochemicals, fluorspar consumption is driven primarily by factors affecting downstream industries. Fluorochemicals, particularly those containing carbon, are very stable and versatile, and new applications continue to be developed. However, numerous environmental, health, and safety issues constrain the use of fluorine, HF, and many other fluorinated substances. These conflicting factors complicate an assessment of the outlook for fluorspar. The following discussion examines fluorspar consumption within three leading industrial sectors.

Aluminum.—Because aluminum produced from scrap does not require either AlF_3 or cryolite, demand for fluorspar is expected to increase with primary aluminum production. Aluminum fluoride produced from FSA may displace some AlF_3 produced from fluorspar. However, because of differing physical properties, the two products are not readily interchangeable.

Chemicals.—Consumption of HF is expected to have an average annual growth rate of 1.8% through 2022. Global demand for refrigeration and air conditioning, particularly in developing countries, continues to increase, driving continued demand for fluorocarbon gases. However, because of increased regulation of fluorinated gases with high GWP, a portion of the refrigerant market is expected to transition to non-fluorinated alternatives, which could temper increased consumption of fluorspar in this sector. Consumption of fluorspar for fluorocarbon production is expected to increase by 300,000 t through 2022. However, by 2025, the proportion used for fluoropolymer feedstock is expected to equal the amount used for fluorogases (Wietlisbach, 2019, p. 12, 22).

Although only a small fraction of downstream consumption, one of the fastest-growing uses of fluorspar is expected to be in lithium-ion battery electrolytes which are typically fluorine-containing lithium salts combined with solvents and other additives. The electrolyte salt industry has its base in the fluorochemical industry, and production and is often partially integrated with downstream production of electrolyte solutions (Roskill Information Services Ltd., 2020, p. 343, 344). The primary salt used in battery electrolytes is lithium hexafluorophosphate ($LiPF_6$), production of which was 28,700 t in 2018. With increased adoption of battery-powered electric vehicles, consumption is expected to more than quintuple by 2025 (Shang, 2019).

Fluxes in Steelmaking.—Metspar consumption varies significantly by geographic region. In Europe and North America, consumption decreased dramatically in the 1990s with decreasing use of open-hearth steelmaking furnaces that used large quantities of fluorspar as a flux. Improvements in steelmaking technology also have reduced the consumption of fluorspar per ton of steel produced. In developing countries, the quantity of fluorspar used as a flux in steelmaking continues to be much higher, but further efficiency improvements are expected to moderate growth.

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TABLE 1

SALIENT FLUORSPAR STATISTICS[1, 2]

		2014	2015	2016	2017	2018
United States:						
Fluorspar:						
Exports:[3]						
Quantity:						
Acid grade, more than 97% calcium fluoride	metric tons	8,650	8,410	6,930	5,180	2,720
Metallurgical grade, 97% or less calcium fluoride	do.	4,760	5,290	5,000	5,760	6,250
Total	do.	13,400	13,700	11,900	10,900	8,970
Average unit value:[4]						
Acid grade, more than 97% calcium fluoride	dollars per metric ton	166	166	159	172	137
Metallurgical grade, 97% or less calcium fluoride	do.	161	153	160	183	156
Imports for consumption:[3]						
Quantity:						
Acid grade, more than 97% calcium fluoride	metric tons	291,000	328,000	328,000	331,000	381,000
Metallurgical grade, 97% or less calcium fluoride	do.	123,000	47,600	55,200	70,400	77,600
Total	do.	414,000	376,000	383,000	401,000	459,000
Average unit value:[5]						
Acid grade, more than 97% calcium fluoride	dollars per metric ton	284	289	273	267	276
Metallurgical grade, 97% or less calcium fluoride	do.	182	249	233	237	258
Reported consumption	metric tons	W	W	W	W	W
Apparent consumption:[6]						
Acid grade, more than 97% calcium fluoride	do.	282,000	320,000	321,000	329,000	378,000
Metallurgical grade, 97% or less calcium fluoride	do.	118,000	42,400	50,200	64,700	71,300
Total	do.	400,000 r	362,000 r	371,000	390,000	450,000
Fluorosilicic acid:						
Production	metric tons	70,100	64,500	44,200 r	39,500	32,500
Sold and used	do.	70,600	63,500	43,200 r	39,000	32,100
Value	thousands	$19,800	$15,500	$14,300 r	$13,500	8,680
Stocks, December 31, consumer and distributor	metric tons	195,000	146,000 e	147,000 e	NA	NA
World, production	do.	6,730,000	5,940,000 r	5,870,000 r	6,680,000 r	6,720,000

eEstimated. rRevised. do. Ditto. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Table includes data available through March 31, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Does not include byproduct or synthetic fluorspar production.

[3]Source: U.S. Census Bureau; data may be adjusted by the U.S. Geological Survey.

[4]Free alongside ship values at U.S. ports.

[5]Cost, insurance, and freight values at U.S. ports.

[6]Imports minus exports.

TABLE 2

U.S. REPORTED CONSUMPTION OF FLUORSPAR, BY END USE[1]

(Metric tons)

	Containing more than 97% calcium fluoride		Containing 97% or less calcium fluoride		Total	
End use or product	2017	2018	2017	2018	2017	2018
Hydrofluoric acid	W	W	--	--	W	W
Metallurgical	W	W	NA	NA	NA	NA
Other[2]	W	W	--	--	W	W
Total	W	W	NA	NA	NA	NA
Stocks, consumer and distributor, December 31	W	W	NA	NA	NA	NA

NA Not available. W Withheld to avoid disclosing company proprietary data; included in “Other.” -- Zero,

[1]Table includes data available through March 31, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]May include cement, enamel, glass and fiberglass, steel castings, and welding rod coatings.

TABLE 3

PRICES OF IMPORTED FLUORSPAR[1]

(Dollars per metric ton)

Source and grade	2017	2018
Acidspar:		
Dry basis, cost, insurance, and freight (c.i.f.) Gulf port, filtercake	260–270	260–270
Chinese, free on board (f.o.b.) China, wet filtercake	400–420	550–580
Mexican, f.o.b. Tampico, filtercake[2]	260–280	400–450
Mexican, f.o.b. Tampico, arsenic <5 parts per million	280–310	NA
South African, f.o.b. Durban, filtercake	200–230	450–490
Metspar, Mexican, f.o.b. Tampico	230–250	300–320

NA Not available.

[1]Table includes data available through March 31, 2021.

[2]Beginning in 2018, price includes material formerly listed as "Mexican, f.o.b. Tampico, arsenic <5 parts per million."

Source: Fastmarkets IM (London).

TABLE 4

U.S. EXPORTS OF FLUORSPAR, BY COUNTRY OR LOCALITY[1, 2]

Country or locality	2017 Quantity (metric tons)	2017 Value[3]	2018 Quantity (metric tons)	2018 Value[3]
Australia	87	$12,600	87	$12,600
Brazil	--	--	166	26,400
Canada	8,290	1,590,000	6,560	994,000
Chile	194	28,600	--	--
China	65	9,480	--	--
Dominican Republic	--	--	642	100,000
El Salvador	36	4,050	--	--
France	143	23,800	--	--
Germany	8	4,400	72	10,500
Hong Kong	308	44,700	--	--
India	--	--	173	25,100
Italy	43	4,800	--	--
Japan	18	2,560	--	--
Korea, Republic of	80	22,700	117	16,000
Malaysia	185	26,800	--	--
Mexico	1,490	169,000	1,110	150,000
Taiwan	--	--	52	13,100
Total	10,900	1,940,000	8,970	1,350,000

-- Zero.

[1]Table includes data available through March 31, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Exports include domestic exports only. Exports for Harmonized Tariff Schedule B numbers 2529.21.0000 and 2829.22.0000.

[3]Free alongside ship values at U.S. ports.

Source: U.S. Census Bureau.

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF FLUORSPAR, BY COUNTRY AND CUSTOMS DISTRICT[1, 2]

	2017		2018	
Country and customs district	Quantity (metric tons)	Value[3] (thousands)	Quantity (metric tons)	Value[3] (thousands)
Containing more than 97% calcium fluoride (CaF_2):				
Canada:				
Houston, TX	--	--	4,700	$1,220
New Orleans, LA	--	--	6,300	2,210
Total	--	--	11,000	3,430
China:				
Baltimore, MD	380	$209	356	222
Houston, TX	17,200	4,810	--	--
New Orleans, LA	5,280	1,510	--	--
New York, NY	--	--	38	22
Total	22,900	6,530	394	244
Germany:				
Houston, TX	510	217	1,080	231
New York, NY	114	51	114	76
Total	624	268	1,190	307
Israel, New Orleans, LA	34	21	--	--
Japan, New York, NY	2	10	630	333
Mexico:				
Baltimore, MD	75	36	--	--
Laredo, TX	20,400	5,680	21,300	5,690
New Orleans, LA	182,000	47,600	214,000	54,800
Philadelphia, PA	19	9	--	--
Total	202,000	53,300	235,000	60,500
Mongolia, Baltimore, MD	152	80	571	381
Russia, Cleveland, OH	--	--	1	14
South Africa, Houston, TX	27,900	5,990	41,700	14,400
Spain:				
Cleveland, OH	60	36	19	13
Houston, TX	20,100	4,630	19,000	6,310
Nogales, AZ	--	--	1	5
Total	20,100	4,670	19,000	6,320
United Kingdom:				
Chicago, IL	177	115	--	--
Houston, TX	6	17	15	18
Total	183	132	15	18
Vietnam:				
Houston, TX	52,500	16,400	61,300	16,400
New Orleans, LA	4,500	993	10,000	2,960
Total	57,000	17,400	71,300	19,400
Grand total	331,000	88,400	381,000	105,000
Containing 97% or less CaF_2:				
Belgium, Los Angeles, CA	--	--	1	4
China:				
Cleveland, OH	--	--	117	84
Los Angeles, CA	52	19	636	395
New Orleans, LA	300	174	--	--
New York, NY	98	62	--	--
Seattle, WA	151	97	106	70
Total	601	353	859	549
Mexico:				
Laredo, TX	2,670	342	3,230	601
New Orleans, LA	67,100	16,000	72,200	17,900
Total	69,800	16,300	75,400	18,500

See footnotes at end of table.

TABLE 5—Continued

U.S. IMPORTS FOR CONSUMPTION OF FLUORSPAR, BY COUNTRY AND CUSTOMS DISTRICT[1, 2]

Country and customs district	2017 Quantity (metric tons)	2017 Value[3] (thousands)	2018 Quantity (metric tons)	2018 Value[3] (thousands)
Containing 97% or less CaF_2:—Continued				
Mongolia:				
Cleveland, OH	--	--	100	83
New Orleans, LA	--	--	1,000	695
Total	--	--	1,100	777
Netherlands, Los Angeles, CA	1	8	--	--
South Africa:				
Baltimore, MD	--	--	27	11
Los Angeles, CA	--	--	1	11
Total	--	--	28	22
Spain:				
Los Angeles, CA	--	--	52	39
New York, NY	--	--	81	50
Total	--	--	133	89
United Kingdom, Chicago, IL	--	--	1	17
Grand total	70,400	16,700	77,600	20,000
Grand total, all grades	401,000	105,000	459,000	125,000

-- Zero.

[1]Table includes data available through March 31, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes acid- and metallurgical-grade fluorspar as reported by Harmonized Tariff Schedule of the United States codes 2529.22.0000 and 2529.21.0000, respectively.

[3]Cost, insurance, and freight values at U.S. ports.

Source: U.S. Census Bureau.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF HYDROFLUORIC ACID (HF), BY COUNTRY OR LOCALITY[1, 2]

Country or locality	2017 Quantity (metric tons)	2017 Value[3] (thousands)	2018 Quantity (metric tons)	2018 Value[3] (thousands)
Canada	744	$1,200	410	$855
China	5,320	5,450	2,550	3,190
Germany	1,360	2,620	1,460	2,920
India	88	87	74	109
Japan	3,900	5,030	1,490	3,820
Korea, Republic of	327	1,130	1,130	1,840
Mexico	110,000	159,000	112,000	165,000
Singapore	274	774	386	1,180
Spain	695	1,060	2,270	3,260
Sweden	--	--	18	70
Taiwan	360	943	438	1,230
United Kingdom	--	--	4	2
Total	123,000	177,000	122,000	183,000

-- Zero.

[1]Table includes data available through March 31, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Import information for hydrofluoric acid is reported by Harmonized Tariff Schedule of the United States code 2811.11.0000.

[3]Cost, insurance, and freight values at U.S. ports.

Source: U.S. Census Bureau.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF CRYOLITE, BY COUNTRY OR LOCALITY[1, 2]

Country or locality	2017 Quantity (metric tons)	2017 Value[3] (thousands)	2018 Quantity (metric tons)	2018 Value[3] (thousands)
Argentina	--	--	338	$216
Canada	756	$217	3,910	1,840
China	180	199	142	165
Denmark	119	206	747	1,310
France	--	--	409	274
Germany	1,950	2,690	1,650	2,330
Hungary	254	403	514	787
Iceland	460	438	627	476
India	2	7	6	9
Italy	6	9	4	6
Japan	5,510	6,880	7,570	9,370
Mexico	20	8	--	--
Netherlands	--	--	34	20
New Zealand	--	--	4	5
Spain	64	55	215	82
Switzerland	43	20	649	491
United Kingdom	537	975	--	--
Total	9,900	12,100	16,800	17,400

-- Zero.

[1]Table includes data available through March 31, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes natural and synthetic cryolite as reported by Harmonized Tariff Schedule of the United States codes 2530.90.1000 and 2826.30.0000, respectively.

[3]Cost, insurance, and freight values at U.S. ports.

Source: U.S. Census Bureau.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM FLUORIDE (AlF_3), BY COUNTRY OR LOCALITY[1, 2]

Country or locality	2017 Quantity (metric tons)	2017 Value[3] (thousands)	2018 Quantity (metric tons)	2018 Value[3] (thousands)
Canada	2,760	$3,480	8,440	$10,800
China	8,180	9,290	5,400	12,000
Italy	480	579	98	164
Mexico	6,160	7,160	11,600	13,700
Norway	3,000	3,140	--	--
Other[4]	24	47	29	49
Total	20,600	23,700	25,600	36,800

-- Zero.

[1]Table includes data available through March 31, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Import information for aluminum fluoride is reported by Harmonized Tariff Schedule of the United States code 2826.12.0000.

[3]Cost, insurance, and freight values at U.S. ports.

[4]Includes all countries and (or) localities with quantities less than 100 metric tons.

Source: U.S. Census Bureau.

TABLE 9

FLUORSPAR: WORLD MINE PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Metric tons)

Country or locality	2014	2015	2016	2017	2018
Afghanistan	4,700	4,108	4,000 [e]	4,000 [e]	4,000 [e]
Argentina	39,433	65,282	14,222	13,696 [r]	14,000 [e]
Brazil:					
Acid grade	6,496	6,084 [r]	6,100 [r, e]	6,100 [r, e]	6,100 [e]
Metallurgical grade	17,353	20,287 [r]	20,300 [r, e]	20,300 [r, e]	20,300 [e]
Total	23,849	26,371 [r]	26,400 [r, e]	26,400 [r, e]	26,400 [e]
Bulgaria	20,000 [e]	20,000 [e]	2,000 [e]	--	--
Burma:[e]					
Acid grade	--	--	--	--	20,000
Metallurgical grade	--	--	--	--	50,000
Total	--	--	--	--	70,000
Canada	--	--	--	NA	20,000 [e]
China[2]	4,310,000	3,820,000	3,730,000 [e]	4,348,000 [r]	4,000,000 [e]
Egypt	900 [e]	1,105	1,000	1,000 [e]	1,000 [e]
Germany, acid grade	58,100	49,801	52,552	45,375 [r]	45,000 [e]
India, metallurgical grade	2,439	2,270	1,920	1,120	1,600 [e]
Iran	78,736	39,286	70,820	70,000 [e]	70,000 [e]
Kazakhstan	65,000 [e]	21,200 [e]	20,000 [e]	--	-- [e]
Kenya, acid grade	74,000	64,395	42,656	-- [r]	--
Mexico:					
Acid grade	631,590	623,740	649,361	692,125	700,000 [e]
Metallurgical grade	478,131	250,000 [e]	250,000 [e]	325,000 [e]	380,000 [e]
Total	1,109,721	874,000 [e]	899,000 [e]	1,020,000 [e]	1,080,000 [e]
Mongolia:					
Acid grade[3]	71,900	47,300	34,100	55,200 [r]	55,000 [e]
Metallurgical grade[4]	303,000	300,000 [r, e]	270,000 [r, e]	325,000 [r, e]	550,000 [e]
Total	374,900	347,000 [r, e]	304,000 [r, e]	380,000 [r, e]	605,000 [e]
Morocco:					
Acid grade	74,854	73,879	66,584	56,395	48,751
Metallurgical grade[e]	4,990	7,010	7,340	19,100	16,600
Total	79,840	80,890	73,920	75,500 [r]	65,308
Namibia, acid grade, 97% calcium fluoride (CaF_2)	65,485 [5]	--	1,495 [6]	--	--
Pakistan	8,961	7,692	6,625	2,263 [r]	3,800 [e]
Russia, unspecified, 55% to 96.4% CaF_2	8,200	3,000 [r]	3,000 [r]	6,000 [r]	6,000 [e]
South Africa:					
Acid grade[e]	150,000	110,000 [r]	146,000 [r]	240,000	220,000
Metallurgical grade[e]	14,000	11,000 [r]	31,000 [r]	14,000 [r]	22,000
Total	164,056	121,316 [r]	177,100 [r]	254,000 [r, e]	242,000 [e]
Spain:					
Acid grade	120,582	130,647	130,131	125,870 [r]	130,000 [e]
Metallurgical grade[7]	5,800	24,635	11,997	12,622 [r]	15,000 [e]
Total	126,382	155,282	142,128	138,492 [r]	145,000 [e]
Thailand:					
Acid grade[e]	33,000 [r]	34,000 [r]	37,000 [r]	25,000 [r]	42,000
Metallurgical grade	4,590	15,095	20,100	5,500	6,000 [e]
Total[e]	37,600 [r]	49,100 [r]	57,100 [r]	30,500 [r]	48,000
Turkey	4,271	6,238	10,339	20,150 [r]	20,000 [e]
United Kingdom, all grades	25,000	17,000	12,000	11,000 [r]	11,000 [e]
Vietnam	50,000 [e]	163,000 [e]	218,876 [r]	236,000 [e]	238,702
Grand total	6,730,000	5,940,000 [r]	5,870,000 [r]	6,680,000 [r]	6,720,000
Of which:					
Acid grade	1,290,000	1,140,000 [r]	1,170,000	1,250,000 [r]	1,270,000
Metallurgical grade	830,000 [r]	630,000 [r]	613,000 [r]	723,000 [r]	1,060,000
Other and unspecified	4,620,000	4,170,000	4,090,000	4,710,000 [r]	4,390,000

See footnotes at the end of the table.

TABLE 9—Continued

FLUORSPAR: WORLD MINE PRODUCTION, BY COUNTRY OR LOCALITY[1]

[e]Estimated. [r]Revised. NA Not available. -- Zero.

[1]Table includes data available through May 20, 2019. All data are reported unless otherwise noted. Grand totals and estimated data are rounded to three significant digits; may not add to totals shown.

[2]As reported by China's Ministry of Land and Resources. Production may include a significant amount of submetallurgical-grade material.

[3]Flotation concentrate, includes some material less than 97% CaF_2.

[4]May include some submetallurgical-grade fluorspar.

[5]Data were reported in wet tons, but have been converted to dry tons to agree with other data in the table.

[6]Likely metallurgical grade.

[7]As reported by the Geological and Mining Institute of Spain, metallurgical grade fluorspar typically contains 70% to 97% CaF_2.