2019 Minerals Yearbook

FLUORSPAR [ADVANCE RELEASE]

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FLUORSPAR

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In 2019, most of the 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 equaled 398,000 metric tons (t), 344,000 t of which was acid grade and 53,800 t of which was metallurgical grade. Total apparent consumption decreased by 12% compared with that in 2018. Estimated world production increased by 3% to 7.46 million metric tons (Mt) (table 1).

Fluorspar is used for its fluorine content. Because of technical and practical considerations, fluorine is seldom consumed in elemental form, but rather as fluorspar, which is the commercial name that refers to crude or beneficiated material that is mined and (or) milled from the mineral fluorite (calcium fluoride, CaF_2). Fluorine has unique properties including a small atomic radius, high electronegativity, lipophilicity, reactivity, and low polarizability. These characteristics contribute to fluorine's ability to form a wide variety of stable compounds. The term fluorine is derived from the Latin word fluere which means to flow and is a reference to the early use of fluorspar as a metallurgical flux (Jaccaud and others, 2012, p. 381; Dreveton, 2015, p. 6–7).

The processing of fluorspar is required to meet certain minimum CaF_2 percentage requirements and reduce undesirable impurities, both of which vary by application and consumer requirements. Fluorspar with a minimum CaF_2 content of 97% is referred to as acid grade (also called acidspar) because of its primary use in the manufacture of HF, and anything with a lower content is referred to as metallurgical grade (also called metspar) because of its primary use as a steelmaking flux. The Harmonized Tariff Schedule of the United States (HTS) only differentiates two categories of fluorspar based on similar criteria. Specifications for both acidspar and metspar have changed over time, vary 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 become far less distinct than the CaF_2 content designation suggests. In addition, 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 is typically around 40% to 50%, much lower than the CaF_2 content of metspar typically used as a steelmaking flux.

Legislation and Government Programs

Petroleum Alkylation.—During the course of an accident investigation at Husky Energy Inc.'s (Canada) petroleum refinery in Superior, WI, the U.S. Chemical Safety and Hazard Information Board (CSB) sent a letter to the U.S. Environmental Protection Agency (EPA) in April 2019 recommending that EPA review and update its 1993 study on the potential health and safety risks related to the accidental release of HF. At the time, HF was used as an alkylation catalyst at approximately one-third of domestic petroleum refineries. The CSB urged the EPA to evaluate whether refineries' risk management plans were sufficient to prevent future HF releases and to study the safety and efficacy of alternative alkylation technologies. The suggestion was based on both the CSB's ongoing investigation of the Superior refinery accident and its previous investigation of a 2015 accident at a refinery in Torrance, CA (U.S. Chemical Safety and Hazard Information Board, 2019a).

Significant New Alternatives Policy Program.—The EPA's Significant New Alternatives Policy (SNAP) program was established under the Clean Air Act Amendments of 1990 section 612 for the purpose of meeting the United States' obligations under the Montreal Protocol on Substances that Deplete the Ozone Layer, a global treaty adopted in 1987 that was subsequently ratified by all members of the United Nations. Because of the ozone-depleting potential of early generations of fluorocarbon gases (chlorofluorocarbons or CFCs and later hydrochlorofluorocarbons or 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, were approved as acceptable alternatives. Although not ozone depleting, HFCs (as well as their predecessors) are in many cases potent greenhouse gases owing to high global warming potential (GWP) and long atmospheric lifecycles. Globally, the adoption of the Kigali Amendment to the Montreal Protocol in 2016 effectively expanded the scope of the treaty to phase down the use of many higher GWP HFCs as well. As of yearend 2019, the United States had not ratified the Kigali Amendment, and a 2017 court case established that the EPA did not have the statutory authority to restrict the use of HFCs on the basis of GWP. However, several States were considering implementing their own HFC regulations (U.S. Court of Appeals for the District of Columbia Circuit, 2017, p. 2–6; Cooling Post Ltd., 2018; U.S. Environmental Protection Agency, undated b, c).

Per- and Polyfluoroalkyl Substances.—Per- and polyfluoroalkyl substances (PFAS) 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. PFAS also have been used in firefighting foams and as a processing aid in the manufacture of fluoropolymers. These substances, particularly long-chain PFAS (PFAS molecules containing eight or more carbon atoms, which are sometimes referred to as C-8), have come under scrutiny in the past 10 to

15 years owing to their environmental persistence, prevalence in the bloodstream of humans, and widespread geographic distribution. PFAS may enter the environment directly or through the degradation of other fluorinated telomers.

Of the estimated 5,000 to 10,000 unique PFAS, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) are the two long-chain PFAS 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. A science panel established as part of a 2001 class action lawsuit involving more than 3,500 personal injury claims related to PFOA determined probable links between PFOA exposure and six health conditions, including high cholesterol, kidney and testicular cancers, pregnancy-induced hypertension and preeclampsia, thyroid disease, and ulcerative colitis (Mancini, 2017; C8 Science Panel, undated).

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 PFAS. 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 February 2019, the EPA released a PFAS Action Plan. In response to public concern about PFAS-related water contamination at sites around the country, the EPA convened a summit of stakeholders in May 2018 and announced several actions, including (1) evaluating the viability of establishing a maximum contaminant level for PFOA and PFOS, (2) evaluating the possible designation of PFOA and PFOS as "hazardous substances" under existing Federal statutory mechanisms, (3) developing groundwater cleanup recommendations for PFOA and PFOS, and (4) developing toxicity values or oral reference doses for hexafluoropropylene oxide dimer acid (GenX™) and perfluorobutane sulfonic acid. The action plan provided updates on EPA's progress on those initial actions and announced additional long- and short-term regulatory and research approaches to reduce exposure to PFAS and further characterize potential human health and environmental risks associated with PFAS (U.S. Environmental Protection Agency, 2019, p. 2).

In July 2019, in response to public concerns about PFAS contamination at military installations and surrounding communities, the U.S. Department of Defense (DOD) established a PFAS Task Force. The DOD previously tested 524 water systems worldwide and identified 401 active and former military sites with known or suspected releases of PFOA or PFOS. The DOD identified 36 drinking water systems where PFOA and (or) PFOS levels exceeded the EPA's health advisory recommendation of 70 parts per trillion and continued to characterize, prioritize, and initiate remediation in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (Superfund). The identified PFAS releases were attributed to the military's use of fluorinated aqueous film forming foams (AFFF) used to extinguish jet-fuel fires. The DOD stopped land-based use of AFFF in maintenance, testing, and training exercises in 2016 and implemented measures to mitigate contamination from AFFF used in emergencies. The DOD agreed to continue researching fluorine-free AFFF alternatives and engaged with other Federal partners in continuing to assess environmental and health effects from PFAS including committing $40 million in funding for the Agency for Toxic Substances and Disease Registry for an exposure assessment at eight military installations and a nationwide health study (Paley, 2019).

In December 2019, Congress passed the fiscal year 2020 National Defense Authorization Act that contained a number of provisions pertaining to PFAS that included (1) immediately prohibiting the use of fluorinated AFFF in training exercises and prohibiting all use of fluorinated AFFF after October 1, 2024; (2) adding Gen X™, PFOA, PFOS, and certain other PFAS to the Toxic Release Inventory; (3) requiring most public water facilities to monitor for PFAS under the Safe Drinking Water Act; and (4) requiring the U.S. Geological Survey (USGS) to establish performance standards for PFAS detection to be used in a nationwide soil- and water-sampling program (Seitz and others, 2019).

In May 2019, PFOA, its salts, and PFOA-related compounds were added to the list of chemicals covered by the Stockholm Convention on Persistent Organic Pollutants, a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or on the environment. Exemptions were included for firefighting foams for vapor suppression and liquid fuel fires subject to certain restrictions; implantable medical devices; the manufacture of certain chemicals used to produce pharmaceutical products; the manufacture of fluoroelastomers for the production of O-rings, v-belts, and plastic accessories for car interiors; the manufacture of polytetrafluoroethylene (PTFE) for certain applications; the manufacture of polyfluoroethylene propylene for the production of high-voltage electrical wire and cables for power transmission; oil- and water-repellant coatings for safety-related textiles; photographic coatings; and photolithography and etching processes in semiconductor manufacture. PFOS, its salts, and perfluorooctane sulfonyl fluoride were added to the treaty in 2009 (United Nations, 2019, p. 55; undated a, b).

Production

In 2019, small amounts of fluorspar may have been produced in Illinois by Hastie Mining & Trucking 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 USGS does not have a data survey for synthetic fluorspar produced in the United States.

In 2019, three companies—J.R. Simplot Co., Mosaic Fertilizer LLC (a subsidiary of The Mosaic Co.), and Nutrien Ltd.—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 three and represented 86% of the total sold or used by producers. In 2019, production was 29,400 t, a 10% decrease compared with 2018 (equivalent to about 47,700 t of fluorspar grading 100% CaF_2) (table 1).

Core Metals Group (Aurora, IN), Hastie Mining & Trucking, and Seaforth Mineral & Ore Co., Inc. (East Liverpool, OH) marketed imported screened and dried 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. As of yearend 2018, the DOE reported that the project had recovered a total of 45,400 t of aqueous HF which was sold into the commercial market (U.S. Department of Energy, 2019, undated).

Consumption

Apparent consumption of fluorspar was 398,000 t, a 12% decrease compared with 450,000 t in 2018 (table 1). Apparent consumption of acid-grade fluorspar decreased by 9% to 344,000 t and that of metallurgical-grade fluorspar decreased by 25% to 53,800 t. Globally, there are three leading fluorspar-consuming industries. The manufacture of HF, the leading source of fluorine in industrial applications and a precursor in 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, AlF_3 production has typically been discussed as a distinct use.) Both 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. Metallurgical-grade fluorspar is used primarily in this application, although acid-grade material may also be 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.

In the United States, FSA was used primarily for water fluoridation, but it also was used as a metal surface treatment and cleaner and for pH adjustment in industrial textile processing and laundries. It 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 13% of global production. 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 (Roskill Information Services Ltd., 2020, p. 2, 376). In 2019, the amount of FSA sold or used by producers in the United States was 32,300 t (table 1), essentially unchanged compared with that in 2018 and was used primarily for water fluoridation.

Aluminum.—Internationally, acid-grade fluorspar was used in the production of AlF_3 and cryolite, which were essential in primary aluminum smelting. Alumina (Al_2O_3) was dissolved in a bath that consists 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) was controlled by the addition of AlF_3, which reacts with the sodium to form cryolite. This reaction resulted in excess bath material, which was drawn off in liquid form, allowed to cool and solidify, and then crushed and reused to start new smelter pots or to compensate for electrolyte losses. This excess material was variously called crushed tapped bath, secondary cryolite, or bath cryolite, as well as other terms. In the aluminum smelting process, AlF_3 was also used to replace fluorine losses (either absorbed by the smelter pot lining or released to the atmosphere as emissions). The AlF_3 requirements of the U.S. aluminum industry were met through imports in 2019 (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), second only to China. HF was used directly in a variety of industrial processes and as an intermediate in the production of organic and inorganic fluorine chemicals. Two companies in the United States used fluorspar to produce HF in 2019—The Chemours Co. (Wilmington, DE) and Honeywell. Major U.S. producers of downstream fluorochemicals that used HF as an intermediate were Arkema Inc., Chemours, Daikin America, Inc., Honeywell, Mexichem Flúor, Inc. (known commercially as Koura), and Solvay Solexis Inc. (Roskill Information Services Ltd., 2020, p. 24, 243).

When used directly, 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 47% of global annual acid-grade fluorspar consumption and an estimated one-third of global annual fluorspar consumption (Roskill Information Services Ltd., 2020, p. 86). Carbon-fluorine bonds are among the strongest bonds in organic chemistry and exhibit many advantageous characteristics including corrosion, oil, water, and temperature resistance. Fluorocarbons can be subdivided into nonfeedstock uses (which are typically emissive) such as aerosols, propellants, and refrigerant gases, which were regulated by SNAP, and feedstock uses (used captively in the manufacture of other chemicals such as fluoropolymers).

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 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. The United States was a leading producer and net exporter of fluoropolymers. Information on domestic fluoropolymer production was not available for 2019; however, a special report for the FluoroCouncil reported that in 2018 combined sales of fluoropolymers and fluoroelastomers totaled 85,000 t valued at $2 billion. Because of often unique and specialized performance requirements for fluoropolymers used 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 were in the manufacture of semiconductors because of their resistance to aggressive etchant chemicals and in a variety of 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%) where fluoropolymers typically were 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 and 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).

Fluorochemical Industry News.—In April 2019, Husky Energy announced that it would continue to use HF as a catalyst in the alkylation unit of its refinery in Superior, WI, which was damaged by an explosion in 2018. Owing to safety concerns about the use of HF in refining operations, residents and public officials had asked the company to consider using a different catalyst. Although the HF tank wasn't damaged, debris from the explosion punctured an asphalt tank in the same vicinity. The company concluded that switching to a different catalyst would not be economical and that it would implement other safety measures to prevent release of HF (Hughlett, 2019).

In June 2019, a series of explosions and subsequent fire destroyed the HF alkylation unit at the Philadelphia Energy Solutions (PES) refinery in Philadelphia, PA. Although a control room operator activated a safety system that drained the HF tank in the alkylation unit, the CSB later determined that an estimated 2.4 t of HF was released as part of the process fluid in the system. The CSB further determined that the initial point of failure was a ruptured pipe elbow that had corroded from contact with the HF in the process fluid, which had not been monitored as part of the PES inspection program. PES later announced that the refinery would be permanently shut down and filed for bankruptcy (U.S. Chemical Safety and Hazard Information Board, 2019b).

In February 2019, Chemours announced the startup of production at its newly constructed refrigerant production facility in Ingleside, TX. The facility would triple Chemours global capacity to produce Opteon™ YF, a hydrofluoroolefin-1234yf refrigerant with low GWP used primarily in automotive air-conditioning systems and as a refrigerant blend in a wide range of applications (Chemours Co., The, 2019).

Steel and Other Uses.—The merchant 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 the fluidity of the slag. Sales also were made to smaller markets such as cement plants, foundries, glass and ceramics plants, and welding rod manufacturers in railcar, truckload, and less-than-truckload quantities. Data on merchant fluorspar sales are withheld to avoid disclosing company proprietary data. In the late 1970s, the United States used more than 500,000 t/yr for these applications. During the past 20 to 30 years, however, fluorspar usage in such industries as steel and glass has declined because of product substitutions or changes in industry practices.

Prices

According to Fastmarkets IM, the yearend price of metallurgical-grade fluorspar from Mexico and acid-grade fluorspar from all leading exporting countries decreased in 2019. The yearend prices of acid-grade fluorspar from China (free-on-board wet filtercake) and South Africa (free-on-board Durban, filtercake) decreased by 25% and 10%, respectively, to $400 to $450 per metric ton compared with prices at yearend 2018. The price of acid-grade fluorspar from Mexico (free-on-board Tampico, filtercake) was $380 to $450 per metric ton, a slight decrease compared with the price at yearend 2018. Metallurgical-grade fluorspar from Mexico was $280 to $320 per metric ton, a 3% decrease compared with the yearend price in 2018 (table 3).

Transportation

The United States depended 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 usually were shipped by ocean freight using bulk carriers of 10,000- to 50,000-t deadweight capacity. Some fluorspar was marketed in bags for small users and shipped by truck.

Foreign Trade

In 2019, U.S. exports of fluorspar decreased by 15% to 7,600 t compared with that in 2018 (table 4). With the absence of fluorspar stocks in the National Defense Stockpile and only a small amount of mined or byproduct fluorspar, exports were likely reexports of imported material. Approximately 70% of exports went to Canada.

In 2019, combined acid- and metallurgical-grade fluorspar imports for consumption totaled 405,000 t, a 12% decrease compared with those in 2018 (table 5). Mexico supplied 70% of total domestic imports. Acid-grade imports equaled 346,000 t, a 9% decrease compared with imports in 2018. The leading suppliers of acid-grade fluorspar to the United States were Mexico (67%) and Vietnam (20%). Metallurgical-grade imports decreased by 23% to 59,500 t, and 91% were from Mexico.

The following imports are compared with those in 2018—imports of HF increased slightly to 124,000 t (table 6); the majority of HF imports were from Mexico (91%). Imports of cryolite increased by 23% to 20,700 t, with Japan (35%) and Canada (26%) as the leading sources (table 7). AlF_3 imports increased by 46% to 37,300 t (table 8); the leading suppliers of AlF_3 were Mexico (49%), Canada (39%), and Italy (8%). The increase in cryolite and AlF_3 imports was likely related to a 23% increase in primary aluminum production in 2019 (Bray, 2021).

World Review

Canada.—In August 2018, Canada Fluorspar (NL) Inc. (CFI), which began producing acid-grade fluorspar in 2018, submitted a project registration for the construction of a marine shipping terminal to The Canadian Environmental Assessment Agency and the Newfoundland and Labrador Department of Municipal Affairs and Environment. CFI had previously planned to construct a marine shipping terminal at Blue Beach Cove on the eastern shore of Newfoundland and Labrador. In the interim, fluorspar had been trucked 45 kilometers to Marystown for export. However, the company had received inquiries for shipments larger than could be accommodated by either location. CFI's new proposed location in Little Lawn Harbour would be closer to the mine site and would accommodate ships up to 72,000 deadweight tonnage, which would facilitate export of up to 200,000 t/yr of acid-grade fluorspar concentrate and 2 million metric tons per year (Mt/yr) of construction aggregate [Canada Fluorspar (NL) Inc., 2019, p. 1–4].

China.—China was the world's leading producer and consumer of AlF_3, fluorocarbons (feedstock and nonfeedstock), fluorspar, and HF. Throughout the 1990s, China was the leading global fluorspar exporter. However, for the previous two decades, Government policy had evolved to discourage exports in favor of development of downstream consuming industries and increased vertical integration and, in 2018, China became a net importer of fluorspar. 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 Mt/yr from 2014 to 2017, accounting for an estimated 58% of total world production in 2019 (table 9). Actual production, however, may have been much higher. The China Non-Metallic Minerals Industry Association (CNMIA) estimated China's fluorspar production to be 6.02 Mt in 2018, based on provincial data. The leading Provinces in terms of production quantity were Hunan, Inner Mongolia, Jiangxi, and Zhejiang. The number of operating mines in the country had decreased steadily 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. Although new resources had been discovered in the western part of the country, transportation costs would be higher. In January 2019, the Ministry of Industry and Information Technology imposed new restrictions on fluorspar mining and beneficiation that included (1) a minimum capacity requirement of 50,000 t/yr for new mines, (2) a minimum capacity of 20,000 t/yr for mine expansion projects, (3) encouraging mines with a capacity of more than 30,000 t/yr to build their own beneficiation lines, (4) establishing minimum recovery rates for mining and beneficiation projects, and (5) encouraging new capacity to be located in areas with the largest reserves. Throughout 2019, the mining industry continued to adapt to evolving regulatory requirements which resulted in the cessation of fluorspar mining in several mining localities including Guangde in Anhui Province, Qilianshan in Gansu Province, and Xinyang in Henan Province (Liao, 2019; Roskill Information Services Ltd., 2020, p. 141–142).

The CNMIA estimated fluorspar consumption to be approximately 6.07 Mt in 2018 and projected it to increase based on data available for the first half of 2019. The increase was attributed primarily to increased consumption in the manufacture of HF. Consumption of metspar (presumably referring to high-grade metallurgical lump) had decreased in recent years, but with a corresponding increase in consumption of briquets. Both forms were typically used as steelmaking fluxes. The transition to greater use of briquets may lend credence to reports that China's high-grade fluorspar deposits have been progressively depleted (Liao, 2019).

In October 2019, the National Development and Reform Commission published its Catalogue of Industrial Restructuring (Version 2019) of industrial activities that were to be promoted, restricted, or eliminated and included many that pertained to the fluorochemical sector. Promoted activities included encouraging the development of low-GWP fluorocarbons, fluoropolymers (especially PTFE fiber), fluoroelastomers, perfluorocarbons, and various chemicals used in the manufacture of lithium-carbon monofluoride and other lithium batteries. HF plants that used outdated technology or had a capacity of less than 5,000 t/yr were to be eliminated, and new HF capacity was restricted except for the manufacture of electronic-grade HF. AlF_3 plants that used a dry manufacturing process (that is, fluorspar as feedstock) with less than a 20,000-t/yr capacity were restricted, and wet-process plants (typically using FSA as feedstock) with less than 5,000-t/yr capacity were to be eliminated. A number of other fluorochemicals, such as CFCs, HCFCs, PFOA, PFOS, and other PFAS, were to be restricted or eliminated primarily in accordance with international treaties (Roskill Information Services Ltd., 2020, p. 143).

Japan and the Republic of Korea.—In July 2019, the Government of Japan imposed restrictions on several key materials used in the manufacture of semiconductors exported to the Republic of Korea that included fluorinated products such as high purity HF, fluorinated polyimides, and photoresists. Exporters were required to apply for a license for each shipment, which was estimated to take up to 3 months to receive. HF was used in semiconductor manufacture as an etchant and as an intermediate in the manufacture of a wide variety of other chemicals used in the process. Japan was estimated to account for 70% of high purity "electronic-grade" HF used as an etchant in semiconductor manufacture, which was highly purified compared with HF used in most other industries. Japan formerly imported fluorspar for the manufacture of HF, but increasingly purified crude HF imported from China. Only one company in the Republic of Korea produced HF; most was imported from China and Japan. Fluorinated polyimides were specialty polymers used in the electronics sector as electrical insulation, flexible substrates, and displays. The fluorinated polyimides that were the subject of the export restrictions were those used in organic light-emitting diodes, displays, and printed circuits that increasingly replaced glass to allow for more flexible, lightweight displays. In the first 5 months of 2019, approximately 94% of the Republic of Korea's fluorinated polyimide imports came from Japan. In response to the export restrictions, the Republic of Korea initiated a trade dispute with the World Trade Organization in September. Because of the relatively small number of qualified suppliers and highly specialized nature of manufacturing processes, a prolonged dispute between the two countries had the potential to disrupt the global availability of semiconductors (Goodman and others, 2019, p. 4–5, 12–17, 24–25).

Mexico.—Mexico was the second-ranked producer and leading exporter of fluorspar globally. Production in 2019 was 1.23 Mt, of which 830,000 t was acid grade and 400,000 t was metallurgical grade. Orbia Advance Corp. S.A.B. de C.V. (formerly Mexichem S.A.B. de C.V.) was an integrated producer of fluorspar, AlF_3, HF, medical propellants, and refrigerant gases. It operated two mines including the Las Cuevas Mine in San Luis Potosi, which was thought to be the largest fluorspar mine in the world. According to Orbia, 80% of its fluorspar production was exported, accounting for 96% of the fluorspar produced in Mexico and 20% of the global fluorspar supply. In 2019, the company increased mined fluorspar capacity and acid-grade floatation plant capacity to 1.7 Mt/yr and more than 800,000 t/yr, respectively, compared with 1.2 Mt/yr and more than 600,000 t/yr in 2018 (Mexichem S.A.B. de C.V., 2019, p. 136; Orbia Advance Corp. S.A.B. de C.V., 2020, p. 69, 97, 100, 103–104, 118).

Mongolia.—From 2014 to 2017, Mongolia's production of fluorspar was between 300,000 and 400,000 t/yr. Production began to increase significantly in 2018, which was primarily attributed to a large increase (more than double) in China's imports. This trend continued in 2019. Fluorspar production was 718,000 t, an increase of 28% compared with 561,000 t (revised) in 2018 (table 9). 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. Most 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 it was more likely used as metspar, owing to increasing difficulty of sourcing high-grade metallurgical lump in China (Rhode, 2019b, p. 33–35).

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. 36–39).

Morocco.—GFL GM Fluorspar SA announced that it would increase acid-grade fluorspar capacity at its mine in Taourirt from 40,000 t/yr to 60,000 t/yr. The operation was established in 2018 as a joint venture between Gujarat Fluorochemicals Ltd. (India) and Global Mines Sarl (Morocco). Concentrate from the operation was 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. announced that it officially opened the Nokeng Fluorspar Mine and plant at Rust de Winter, Gauteng, on August 1, 2019. The Nokeng Mine is in the Bushveld Complex directly south of the Minersa Group's Vergenoeg Mine, the country's only other operational fluorspar mine. The flotation plant was designed to process blended ore from two hematite-fluorspar deposits, the Outwash Fan and Plattekop. The company expected to produce 180,000 t/yr of acid-grade fluorspar and 30,000 t/yr metallurgical-grade fluorspar briquets. Based on production from the two ore bodies, the company estimated a 19-year mine life. However, the mining complex included a third partially explored ore body, the Wiltin, that the company believed could extend the mine life. The company also announced that it was preparing a Definitive Feasibility Study for its Wallmannsthal project and was in the process of securing financing to build a 60,000-t/yr HF plant and a 60,000-t/yr AlF_3 plant in Ekandustria, Gauteng, which it expected would support the Government's Fluorochemical Expansion Initiative to develop downstream processing capability (Wagner, 2018, p. 3, 11; Sephaku Fluoride Ltd., 2019).

Outlook

Because of fluorspar's role as the basic material for almost all other fluorochemicals, fluorspar consumption is driven primarily by factors affecting the 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 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 only. 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 nonfluorinated 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. Although the fluorocarbon market is expected to continue to grow overall, ongoing regulatory mechanisms are expected to constrain growth in nonfeedstock applications and, by 2025, the proportion used for fluoropolymer feedstock is expected to nearly equal the amount used for fluorogases (Wietlisbach, 2019, p. 12, 19).

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 is often partially integrated with downstream production of electrolyte solutions (Roskill Information Services Ltd., 2020, p. 343–344). The primary salt used is lithium hexafluorophosphate ($LiPF_6$), the global production of which was 28,700 t in 2018. With increased adoption of electric battery vehicles, production 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 unit consumption of fluorspar per unit ton of steel produced. In less developed countries, however, the quantity of fluorspar used as a flux in steelmaking continues to be higher, but further efficiency improvements are expected to moderate growth.

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TABLE 1

SALIENT FLUORSPAR STATISTICS[1, 2]

		2015	2016	2017	2018	2019
United States:						
Exports:[3]						
Quantity:						
Acid grade, containing more than 97% calcium fluoride (CaF_2)	metric tons	8,410	6,930	5,180	2,720	1,880
Metallurgical grade, containing not more than 97% CaF_2	do.	5,290	5,000	5,760	6,250	5,720
Total	do.	13,700	11,900	10,900	8,970	7,600
Average unit value:[4]						
Acid grade, containing more than 97% CaF_2	dollars per metric ton	166	159	172	137	120
Metallurgical grade, containing less than 97% CaF_2	do.	153	160	183	156	156
Imports for consumption:[3]						
Quantity:						
Acid grade, containing more than 97% CaF_2	metric tons	328,000	328,000	331,000	381,000	346,000
Metallurgical grade, containing less than 97% CaF_2	do.	47,600	55,200	70,400	77,600	59,500
Total	do.	376,000	383,000	401,000	459,000	405,000
Average unit value:[5]						
Acid grade, containing more than 97% CaF_2	dollars per metric ton	289	273	267	276	304
Metallurgical grade, containing less than 97% CaF_2	do.	249	233	237	258	292
Reported consumption	metric tons	W	W	W	W	W
Apparent consumption:[6]						
Acid grade, containing more than 97% CaF_2	do.	320,000	321,000	326,000 [r]	378,000	344,000
Metallurgical grade, containing less than 97% CaF_2	do.	42,400	50,200	64,700	71,300	53,800
Total	do.	362,000	371,000	390,000	450,000	398,000
Fluorosilicic acid:						
Production	metric tons	64,500	44,200	39,500	32,500	29,400
Sold or used	do.	63,500	43,200	39,000	32,100	32,300
Value, sold or used	thousands	$15,500	$14,300	$13,500	$8,680	$6,960
Stocks, December 31, consumer and distributor	metric tons	146,000 [e]	147,000 [e]	NA	NA	NA
World, production	do.	6,140,000 [r]	5,640,000 [r]	6,730,000 [r]	7,240,000 [r, e]	7,460,000 [e]

[e] Estimated. [r] Revised. do. Ditto. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] Table includes data available through September 10, 2020. 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 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] Defined as imports minus exports.

TABLE 2

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

(Metric tons)

	Containing more than 97% calcium fluoride		Containing not more than 97% calcium fluoride		Total	
End use or product	2018	2019	2018	2019	2018	2019
Hydrofluoric acid	NA	NA	--	--	NA	NA
Metallurgical	W	W	W	W	W	W
Other[2]	W	W	--	--	W	W
Total	W	W	W	W	W	W
Stocks, consumer and distributor, December 31	W	W	NA	NA	NA	NA

NA Not available. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1] Table includes data available through September 10, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

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

TABLE 3
PRICES OF IMPORTED FLUORSPAR[1]

(Dollars per metric ton)

Source and grade	2018	2019
Acid grade:		
Dry basis, cost, insurance, and freight (c.i.f.) Gulf port, filtercake	260–270	NA
Chinese, free on board (f.o.b.) China, wet filtercake	550–580	400–450
Mexican, f.o.b. Tampico, filtercake[2]	400–450	380–450
South African, f.o.b. Durban, filtercake	450–490	400–450
Metallurgical grade, Mexican, f.o.b. Tampico	300–320	280–320

NA Not available.

[1] Table includes data available through September 10, 2020.

[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	2018 Quantity (metric tons)	2018 Value[3]	2019 Quantity (metric tons)	2019 Value[3]
Australia	87	$12,600	101	$14,600
Brazil	166	26,400	4	2,720
Canada	6,560	994,000	5,330	771,000
Chile	--	--	60	18,500
Dominican Republic	642	100,000	861	147,000
Germany	72	10,500	--	--
India	173	25,100	--	--
Korea, Republic of	117	16,000	63	10,200
Mexico	1,110	150,000	1,170	150,000
Taiwan	52	13,100	10	6,130
Total	8,970	1,350,000	7,600	1,120,000

-- Zero.

[1] Table includes data available through August 27, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2] Exports include domestic exports only for 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]

	2018		2019	
Country and customs district	Quantity (metric tons)	Value[3] (thousands)	Quantity (metric tons)	Value[3] (thousands)
Acid grade, containing more than 97% calcium fluoride (CaF_2):				
Canada:				
Houston, TX	4,700	$1,220	4,810	$1,250
New Orleans, LA	6,300	2,210	6,560	2,600
Total	11,000	3,430	11,400	3,850
China:				
Baltimore, MD	356	222	--	--
Houston, TX	--	--	12,700	6,020
New York, NY	38	22	--	--
Total	394	244	12,700	6,020
France, Savannah, GA	--	--	38	21
Germany:				
Charleston, SC	--	--	8	5
Houston, TX	1,080	231	444	73
New York, NY	114	76	38	30
Total	1,190	307	490	107
Japan, New York, NY	630	333	882	476
Mexico:				
Laredo, TX	21,300	5,690	10,000	3,120
New Orleans, LA	214,000	54,800	221,000	61,500
Total	235,000	60,500	231,000	64,600
Mongolia, Baltimore, MD	571	381	799	484
Russia, Cleveland, OH	1	14	--	--
South Africa, Houston, TX	41,700	14,400	9,990	4,500
Spain:				
Cleveland, OH	19	13	--	--
Houston, TX	19,000	6,310	10,100	4,640
Nogales, AZ	1	5	1	6
Total	19,000	6,320	10,100	4,640
United Kingdom, Houston, TX	15	18	86	23
Vietnam:				
Houston, TX	61,300	16,400	63,600	18,900 [e]
New Orleans, LA	10,000	2,960	5,030	1,520 [e]
Total	71,300	19,400	68,600	20,400 [e]
Grand total, acid grade	381,000	105,000	346,000	105,000 [e]
Metallurgical grade, containing not more than 97% CaF_2:				
Belgium, Los Angeles, CA	1	4	--	--
Canada, Houston, TX	--	--	4,110	1,890
China:				
Cleveland, OH	117	84	81	56
Los Angeles, CA	636	395	416	240
New Orleans, LA	--	--	75	50
Seattle, WA	106	70	158	103
Total	859	549	730	449
Germany, Great Falls, MT	--	--	6	4
India, Los Angeles, CA	--	--	93	54
Mexico:				
Laredo, TX	3,230	601	2,100	354
New Orleans, LA	72,200	17,900	52,100	14,400
Total	75,400	18,500	54,200	14,800
Mongolia:				
Cleveland, OH	100	83	--	--
New Orleans, LA	1,000	695	336	198
Total	1,100	777	336	198
Netherlands, Los Angeles, CA	--	--	1	4
South Africa:				
Baltimore, MD	27	11	--	--
Los Angeles, CA	1	11	--	--
Total	28	22	--	--

See footnotes at end of table.

TABLE 5—Continued
U.S. IMPORTS FOR CONSUMPTION OF FLUORSPAR, BY COUNTRY AND CUSTOMS DISTRICT[1, 2]

	2018		2019	
Country and customs district	Quantity (metric tons)	Value[3] (thousands)	Quantity (metric tons)	Value[3] (thousands)
Metallurgical grade, containing not more than 97% CaF_2:—Continued				
Spain:				
Los Angeles, CA	52	39	--	--
New York, NY	81	50	--	--
Total	133	89	--	--
United Kingdom, Chicago, IL	1	17	--	--
Grand total, metallurgical grade	77,600	20,000	59,500	17,400
Grand total, all grades	459,000	125,000	405,000	123,000

[e] Estimated. -- Zero.

[1] Table includes data available through August 27, 2020. 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; data adjusted by U.S. Geological Survey.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF HYDROFLUORIC ACID, BY COUNTRY OR LOCALITY[1, 2]

	2018		2019	
Country or locality	Quantity (metric tons)	Value[3] (thousands)	Quantity (metric tons)	Value[3] (thousands)
Belgium	--	--	18	$42
Canada	410	$855	309	771
China	2,550	3,190	2,520	3,080
Germany	1,460	2,920	1,190	2,820
India	74	109	536	648
Israel	--	--	15	17
Japan	1,490	3,820	2,110	5,210
Korea, Republic of	1,130	1,840	1,900	4,270
Mexico	112,000	165,000	113,000	179,000
Netherlands	--	--	18	23
Singapore	386	1,180	290	920
Spain	2,270	3,260	1,870	2,930
Sweden	18	70	--	--
Taiwan	438	1,230	640	1,710
United Kingdom	4	2	--	--
Total	122,000	183,000	124,000	202,000

-- Zero.

[1] Table includes data available through August 27, 2020. 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	2018 Quantity (metric tons)	2018 Value[3] (thousands)	2019 Quantity (metric tons)	2019 Value[3] (thousands)
Argentina	338	$216	394	$269
Bahrain	--	--	65	45
Belgium	--	--	158	132
Brazil	--	--	207	131
Canada	3,910	1,840	5,460	2,420
China	142	165	115	180
Côte d'Ivoire	--	--	17	24
Denmark	747	1,310	748	1,380
France	409	274	841	628
Germany	1,650	2,330	1,370	1,930
Hungary	514	787	691	1,130
Iceland	627	476	1,160	854
India	6	9	39	59
Italy	4	6	--	--
Japan	7,570	9,370	7,280	8,990
Mexico	--	--	21	9
Mozambique	--	--	1,550	1,180
Netherlands	34	20	--	--
New Zealand	4	5	--	--
Norway	--	--	33	21
Spain	215	82	25	21
Switzerland	649	491	538	432
United Arab Emirates	--	--	32	21
Total	16,800	17,400	20,700	19,900

-- Zero.

[1] Table includes data available through August 27, 2020. 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, BY COUNTRY OR LOCALITY[1, 2]

Country or locality	2018 Quantity (metric tons)	2018 Value[3] (thousands)	2019 Quantity (metric tons)	2019 Value[3] (thousands)
Canada	8,440	$10,800	14,400	$10,400
China	5,400	12,000	259	437
Italy	98	164	3,010	5,800
Jordan	--	--	1,140	1,800
Mexico	11,600	13,700	18,400	30,500
Other[4]	29	49	99	254
Total	25,600	36,800	37,300	49,200

-- Zero.

[1] Table includes data available through August 27, 2020. 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 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[2]	2015	2016	2017	2018	2019
Afghanistan	4,108	7,600 [r, e]	7,500 [r, e]	11 [r, e]	1,000 [e]
Argentina	65,282	14,222	13,696	7,924 [r]	8,000 [e]
Brazil:					
Acid grade	5,931 [r]	6,290 [r]	6,300 [r, e]	6,300 [r, e]	6,300 [e]
Metallurgical grade	17,693 [r]	11,970 [r]	12,000 [r, e]	12,000 [r, e]	12,000 [e]
Total	23,624 [r]	18,260 [r]	18,300 [r, e]	18,300 [r, e]	18,300 [e]
Bulgaria	20,000 [e]	2,000 [e]	--	--	--
Burma:[e]					
Acid grade	--	--	--	20,000	36,000
Metallurgical grade	13,000 [r]	7,000 [r]	3,000 [r]	50,000	17,000
Total	13,000 [r]	7,000 [r]	3,000 [r]	70,000	53,000
Canada	--	--	NA	35,000 [r, e]	80,000 [e]
China[2]	3,979,500 [r]	3,470,000 [r]	4,380,000 [r]	4,300,000 [r, e]	4,300,000 [e]
Egypt	1,105	1,000	1,000 [e]	1,000 [e]	1,000 [e]
Germany, acid grade	49,801	52,552	45,375	49,197 [r]	50,000 [e]
India, metallurgical grade	2,270	1,920	1,120	1,270 [r]	1,424
Iran	39,286	70,820	55,297 [r]	55,000 [r, e]	55,000 [e]
Kazakhstan[3]	80,000 [r, e]	80,000 [r, e]	80,000 [r, e]	80,000 [r, e]	87,800
Kenya, acid grade	64,395	42,656	--	--	--
Mexico:					
Acid grade	623,740	649,361	692,125	770,000 [r, e]	830,000 [e]
Metallurgical grade[e]	250,000	250,000	325,000	410,000 [r]	400,000
Total	874,000 [e]	899,000 [e]	1,020,000 [e]	1,182,058 [r, 4]	1,231,465 [4]
Mongolia:					
Acid grade[5]	47,300	34,100	55,200	80,700 [r]	47,500
Metallurgical grade[e]	270,000 [r]	240,000 [r]	280,000 [r]	480,000 [r]	670,000
Total[e]	317,000 [r]	274,000 [r]	335,000 [r]	561,000 [r]	718,000
Morocco:					
Acid grade	73,879	66,584	56,395	69,000 [r, e]	69,000 [e]
Metallurgical grade	7,011 [r]	7,336 [r]	19,105 [r]	19,000 [r, e]	19,000 [e]
Total	80,890	73,920	75,500	87,900 [r, 6]	88,000 [e]
Namibia, acid grade, 97% calcium fluoride (CaF_2)	--	1,495 [7]	--	11 [r, 8]	--
Pakistan	7,692	6,625	42,000 [r, e]	50,000 [r, e]	100,000 [e]
Russia, unspecified, 55% to 96.4% CaF_2	3,000	3,000	2,700 [r]	6,000	6,000 [e]
South Africa:[9]					
Acid grade[e]	110,000	146,000	206,000 [r]	240,000 [r]	190,000
Metallurgical grade[e]	11,000	31,000	12,000 [r]	20,000 [r]	20,000
Total	121,316	177,280 [r]	218,399 [r]	260,000 [r, e]	210,000 [e]
Spain:					
Acid grade	130,647	130,131	125,870	145,428 [r]	120,000 [e]
Metallurgical grade[10]	24,635	11,997	12,622	19,009 [r]	19,000 [e]
Total	155,282	142,128	138,492	164,437 [r]	139,000 [e]
Thailand:					
Acid grade[e]	39,000 [r]	37,000	25,000	36,000 [r]	28,000
Metallurgical grade	15,095	20,100	5,500	16,700 [r]	17,747
Total[e]	54,100 [r]	57,100	30,500	52,700 [r]	45,700
Turkey	6,238	10,339	20,150	6,200 [r]	6,000 [e]
United Kingdom, all grades	17,000	12,000	11,000	11,000	20,000 [e]
Vietnam	163,000 [e]	218,876	234,905 [r]	238,702	238,003
Grand total	6,140,000 [r]	5,640,000 [r]	6,730,000 [r]	7,240,000 [r, e]	7,460,000 [e]
Of which:					
Acid grade	1,140,000	1,170,000	1,210,000 [r]	1,420,000 [r, e]	1,380,000 [e]
Metallurgical grade	611,000 [r]	581,000 [r]	670,000 [r]	1,030,000 [r]	1,180,000
Other and unspecified	4,390,000 [r]	3,900,000 [r]	4,850,000 [r]	4,790,000 [r, e]	4,900,000 [e]

See footnotes at end of table.

TABLE 9—Continued

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

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

[1] Table includes data available through October 23, 2020. All data are reported unless otherwise noted. Grand totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2] As reported by China's Ministry of Natural Resources. May not include production from operations that do not meet the Government's minimum mining and processing requirements. The China Non-Metallic Minerals Industry Association estimated that actual production in 2018 was approximately 6 million metric tons.

[3] Production likely included a significant quantity of unbeneficiated material.

[4] Quantities by grade are estimated. Total production was reported as shown.

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

[6] In 2018, total fluorspar production as reported by the Office National des Hydrocarbures et des Mines [Morocco] was 87,874 metric tons.

[7] Likely metallurgical grade.

[8] Production was reported as semiprecious fluorite crystals.

[9] Quantities by grade were estimated. Total production is reported as follows: 2015—121,316; 2016—177,280; and 2017—218,399.

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