SCRREEN2

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Solutions for CRitical Raw materials - a European Expert Network

FACTSHEETS UPDATES **BASED ON THE EU FACTSHEETS 2020**

FLUORSPAR

AUTHOR(S):

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FLUORSPAR

OVERVIEW

Fluorspar is the commercial name for the mineral fluorite (calcium fluoride, CaF_2). Fluorite is a colourful, widely occurring mineral that occurs globally with significant deposits in over 9,000 areas. Fluorspar is mainly used in steel and iron making, refrigeration and air conditioning, aluminium making, solid fluoropolymers for cookware and cable insulation, fluorochemicals, nuclear uranium fuel and in processes for oil refining.

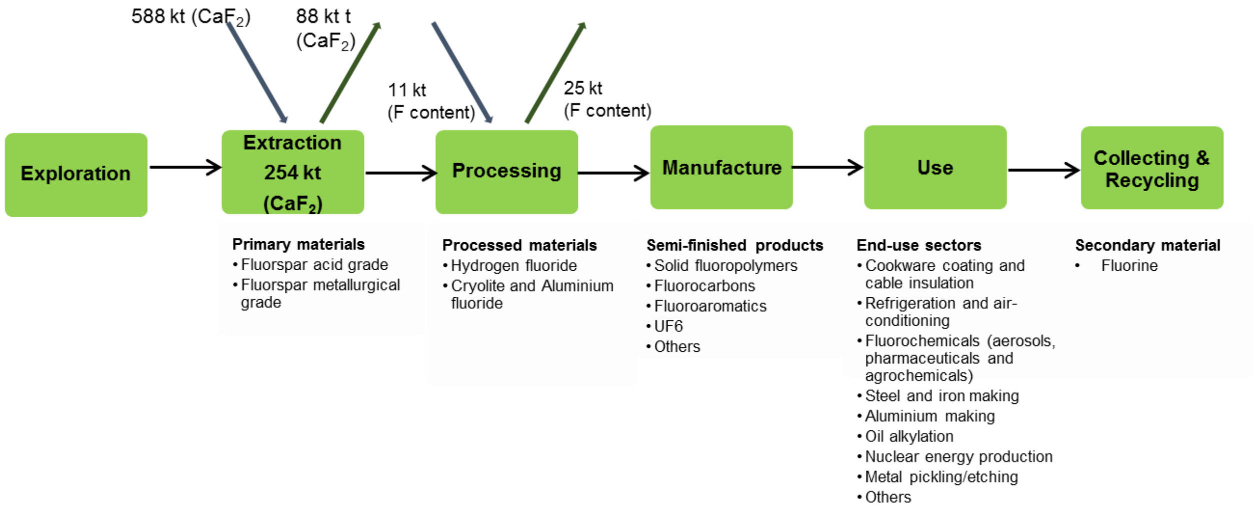

Figure 1. Simplified value chain for fluorspar in the EU[1]

Table 1. Fluorspar supply (mining) and demand (metspar 25292100 & acidspar 25292200) in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
6,697,000	China 56% Mexico 20% Mongolia 7% Vietnam 3% South Africa 3%	654,922	10%	Mexico 33% Spain 23% South Africa 11% Germany 8% China 6%	60%

Prices: Prices of fluorspar depend on the fluorspar grade and country of origin, with China, South Africa and Mexico being the biggest exporters (OEC, 2021). Fluorspar is traded within fixed price year-long contracts, thus, price volatility in specific markets (e.g., prices changes in China and South Africa between 2012 and 2014) does not have a direct effect on global prices (BGS, 2011). Additionally, the EU has increased fluorspar production to become more independent from market-driven price rises (GMI, 2018).

[1] JRC elaboration on multiple sources (see next sections)

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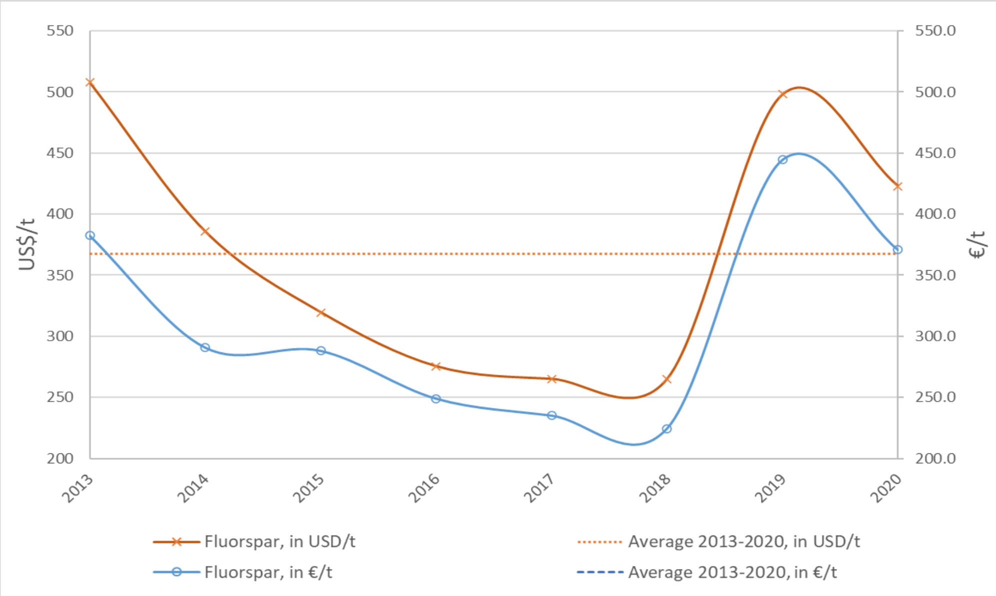

Figure 2. Annual average price of fluorspar between 2000 and 2020 (USGS, 2021)[2].

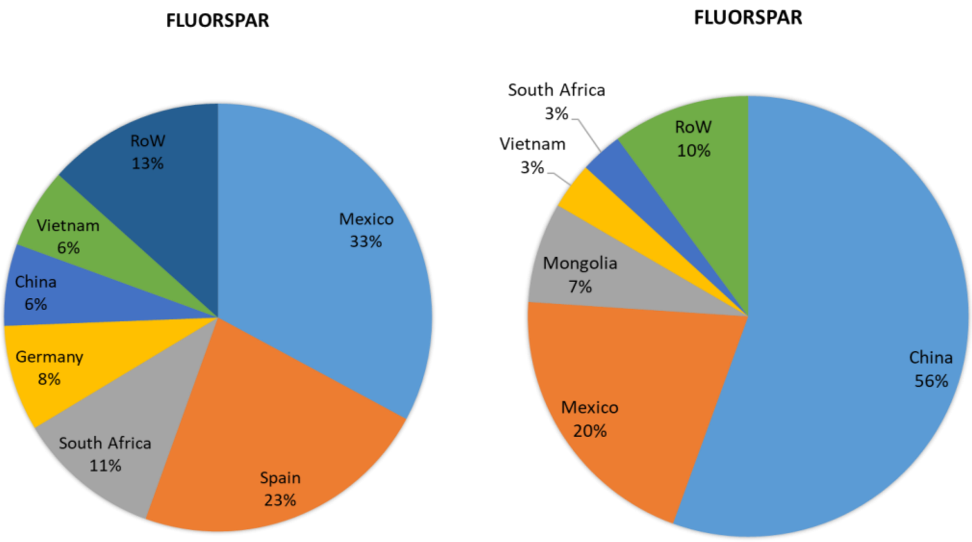

Figure 3. EU sourcing of fluorspar and global mine production (update)

Primary supply: The world annual production of fluorspar ores in average between 2012 and 2016 is around 6,400 ktonnes of CaF2 content, extracted mainly in China and Mexico. Global production in 2020 was 7.6 Mt. Main producing countries were China (57%), Mexico (16%), Mongolia (9.5%), South Africa (4.2%) and Vietnam (3.2%) (USGS 2021). In 2020, China's mine production was the world's largest, with 4.3 million tonnes of fluorspar. Second largest was Mexico with 1200 tonnes and the third was Mongolia with 720 tonnes (Statista 2022)

[2] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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Secondary supply: Fluorspar is recycled only to a minor extent since its uses are dissipative, or recycling is not practicable (Sundqvist Oeqvist, Pr. Lena et al. ,2018).

Uses: Fluorspar is used as a flux in iron and steel making furnaces, where it brings various benefits to the smelting process (Bide, 2011). Additionally, AlF_3 and cryolite is used for aluminium processing and hydrogen fluoride (HF) for pickling/etching applications, both process internal.

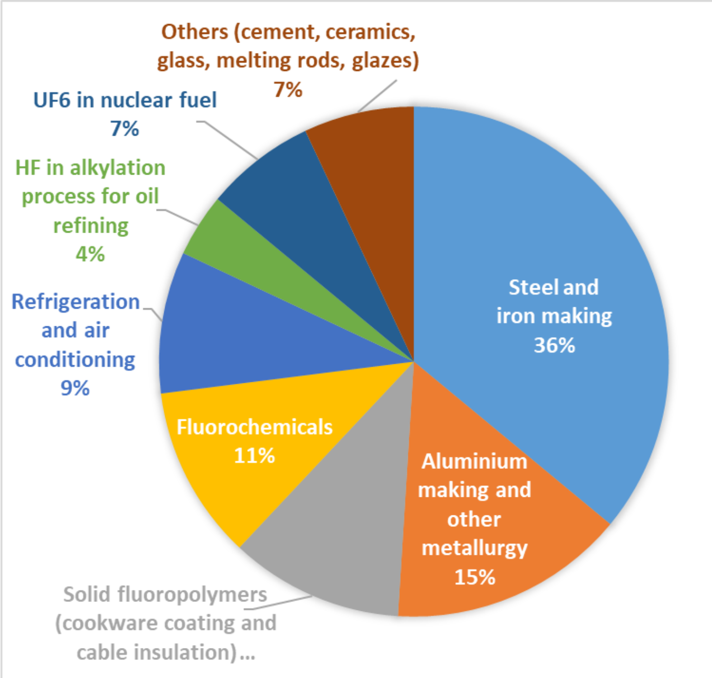

Figure 4: EU uses of Fluorspar

Substitution: In the iron and steel making sector substitutes exist but come with a loss of performance. Possible alternatives are calcium aluminate/chloride, aluminium smelting dross, borax, iron oxides, manganese ore, silica sand and titanium oxide (Tercero Espinoza, 2015). In electrolysis-based aluminium production, fluorspar cannot be substituted, but fluorspar-free carbothermic reduction processes are conceivable (Tercero Espinoza, 2015).

Table 2. Uses and possible substitutes

Use	Percentage*	Substitutes	Sub share	Cost	Performance
Steel and iron making	36%	Calcium aluminate	25%	Slightly higher costs (up to 2 times)	Reduced
	36%	Aluminium smelting dross	25%	Slightly higher costs (up to 2 times)	Reduced
Solid fluoropolymers (cookware coating and cable insulation)	11%	Plastics	5%	Similar or lower costs	Reduced
	11%	Stainless steel	5%	Similar or lower costs	Reduced
	11%	Ceramics	5%	Slightly higher costs (up to 2 times)	Reduced
	11%	Aluminium	2%	Similar or lower costs	Reduced

*Estimated EU27 end use shares fluorospar, SCRREEN, 2019; Data source: Eurostat, 2019, validated by SCRREEN experts, 2022).

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Other issues: Artisanal and small-scale mining represent a large share of global production (e.g. in Mongolia; Barreto et al., 2018), which implies health problems due to fluoride exposure and occupational safety issues (German Environment Agency, 2020). Fluoride intake has both beneficial and negative effects: it reduces the incidence of dental caries but may cause tooth enamel and skeletal fluorosis in case of prolonged exposure to high concentrations (WHO, 2019). There is limited literature on the environmental impacts of fluorspar extraction and concentration in a life cycle perspective. In their LCA study with case application to the Lujar mine (Spain), (Lai et al. 2021) report that the carbon footprint associated with the production of 1 tonne of fluorspar concentrate (79.2 % CaF_2) amounts to 174 kg CO2-eq. The main contributions to impacts are due to diesel consumption by the machinery and the on-site generators in the mining and loading/hauling steps (main contribution regarding 11 impact categories out of 16), and to the mine infrastructure/equipment (main contribution regarding 4 impact categories).

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MARKET ANALYSIS, TRADE AND PRICES

GLOBAL MARKET

Table 3. Fluorspar supply (mining) and demand (metspar 25292100 & acidspar 25292200) in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
6,697,000	China 56% Mexico 20% Mongolia 7% Vietnam 3% South Africa 3%	654,922	10%	Mexico 33% Spain 23% South Africa 11% Germany 8% China 6%	60%

Fluorspar is mined in over 20 countries. China is by far the largest mine producer of fluorspar, with an average annual production between 2016 and 2020 of more than 55% of global supply. Another major producing country is Mexico with roughly 20% of annual production. Mongolia has expanded its production greatly and is now the third most important fluorspar-mining country.

Fluorspar is graded according to fluorspar content, impurities and particle size into acid-grade, metallurgical grade and ceramic grade (BGS, 2011). Most of the fluorspar consumed and traded is either acidspar (acid grade: more than 97% CaF_2) or metspar (subacid grade incl. ceramic and metallurgical grade: 80-97% CaF_2). According to Roskill (2020), about 65-70% of global fluorspar production is acidspar. China is the world's largest market for acidspar (59% in 2018), followed by North America (16%) and Europe (11%). China is also by far the largest consumer of metspar (56% in 2018). Other major consuming countries are the CIS countries, North America, EU, South America, Japan, India and other Asian countries (Roskill, 2020).

The largest fluorspar-mining company is Koura in Mexico, it is also a global leader in development, manufacture and supply of fluorspar. Another important producer is Minerales y Productos Derivados SA (Minersa) with operations in Spain and South Africa (Vergenoeg Mining Company). In China, the world's largest fluorspar producer, the major companies include China Kings Resources Group, Sinochem Lantian and CentralFluor Industries Group. In Mongolia Mongol Juyuanli and Mongolrostsvetmet (Monros) are the largest fluorspar miners.

As common for industrial minerals, fluorspar is traded mainly via long-term contracts. However, some material is sold on the spot market.

Globally, fluorspar is used mainly in three industry fields:

- -Chemical sector, accounting for approximately 40 to 48% of the annual global fluorspar consumption.
- -Primary aluminium smelting, approximately 15 to 19% of the global consumption.
- -Flux in steelmaking, accounting for 33 to 35% of the global consumption (Roskill, 2020; USGS, 2020).

Other applications of fluorspar include use in the manufacture of cement, ceramics, enamel, glass, and welding rod coatings.

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ADDITIONAL INFORMATION

China is not only the largest producing country in the world, but also the largest metspar importer since 2018.

China has developed its own fluorine value chain and has increasing demand for fluorspar for domestic processing. Chinese environmental inspections since 2017 as well as winter production cuts have made production more difficult and mine closures were prompted since 2017. This was compounded by the closure of several fluorspar mines around the world (e.g. Russia, Kenya, Namibia). Subsequently, prices in China rose rapidly in 2017. Fluorspar prices outside China increased significantly as supply disruptions in China hit international markets.

Since 2018 new mines have opened. Examples are Canada Fluorspar (Canada) and SepFluor (South Africa). In consequence, fluorspar production of these countries increased in 2019 and 2020. Production in Mexico and Mongolia has also expanded significantly since 2018/2019.

In 2020 and 2021 the COVID-19 pandemic has disrupted the supply chain, logistics and transport industries. This also affected the fluorspar industry. Fluorspar transport has been partly disrupted and transport freight fees has been significantly higher than usual.

In the coming years the future demand for fluorspar will also depend on the development and use of fluorocarbon substitutes as well as alternative sources of fluorine. Through the implementation of the Montreal and Kyoto Protocols and the European F-Gas Regulation on fluorinated greenhouse gases, many fluorine-containing compounds have been and are currently being replaced by other substances or newly developed fluorine compounds. Hydrofluoroolefins (HFOs) and mixtures based on HFOs are considered to be the most likely replacement for hydrofluorocarbons (HFCs) for due to their low GWP (USGS, 2020).

EU TRADE

For the purpose of this assessment, fluorspar is evaluated at both, extraction and processing stage.

Table 4 Relevant Eurostat CN trade codes for fluorspar

Mining		Processing/refining	
CN trade code	**Title**	**CN trade code**	**title**
25292200	Fluorspar containing by weight > 97% calcium fluoride ('acid grade')	28111100	Hydrogen fluoride "hydrofluoric acid"
		28263000	Sodium hexafluoroaluminate "synthetic cryolite"
		28261200	Fluoride of aluminium
25292100	Fluorspar containing by weight <= 97% calcium fluoride ('metallurgical grade')		

Figure 5 and Figure 6 show the EU trade of fluorspar at mining stage between 2000 and 2021. The EU was a net importer of fluorspar at mine stage in each year of this period. In the case of acid-grade fluorspar (containing by weight more than 97% calcium fluoride), there was a wide deficit in the EU trade balance: over

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the period 2000-2021, the EU imports varied between 321 and 562 thousand tonnes p.a., while the yearly EU exports were in the range between 3.8 and 35.5 thousand tonnes. The EU trade in metallurgical-grade fluorspar (containing by weight 97% or less calcium fluoride) was more balanced, at least, since the mid-2010; the imports varied between 118 and 279 thousand tonnes p.a., and the exports were in the range between 4 and 123 thousand tonnes p.a.

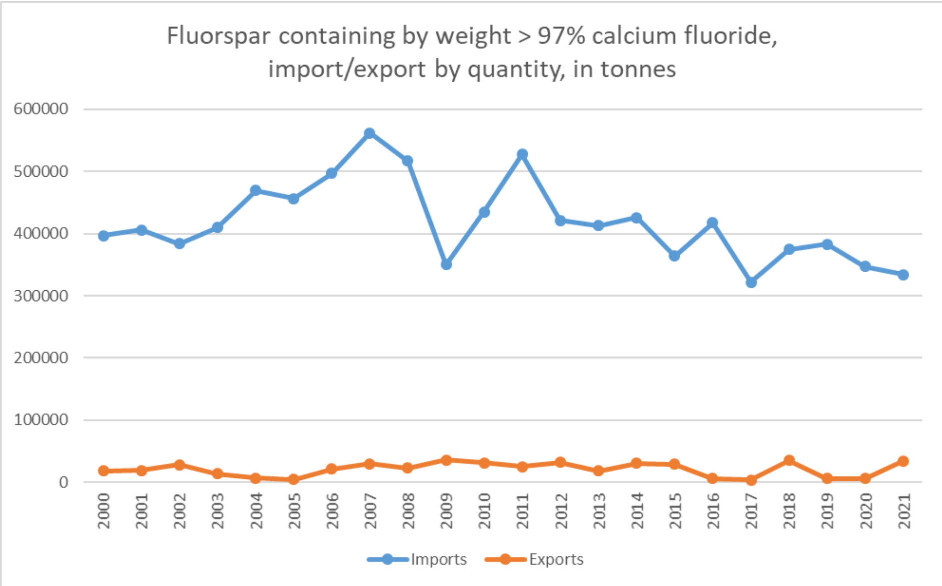

Figure 5 EU trade flows of acid-grade fluorspar, from 2000 to 2021 (based on Eurostat, 2021).

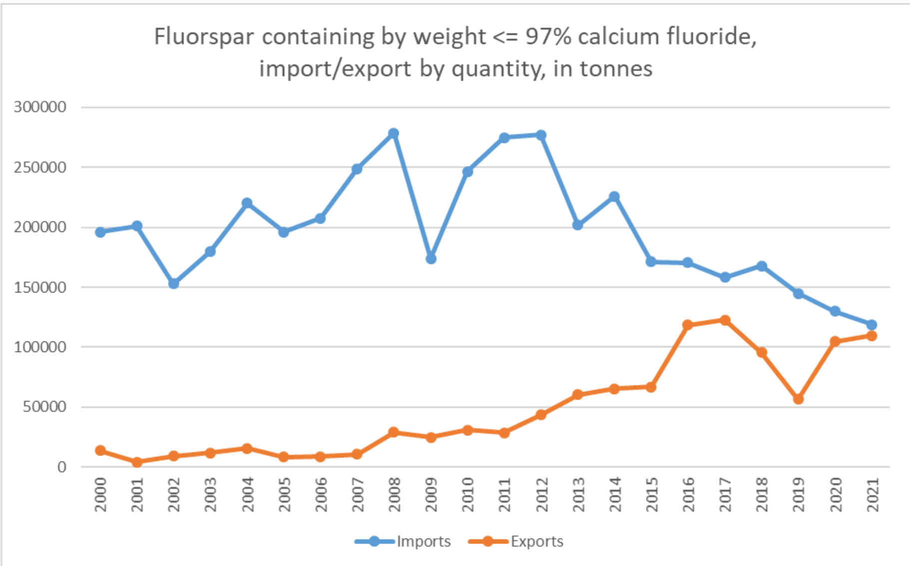

Figure 6 EU trade flows of metallurgical-grade fluorspar, from 2000 to 2021 (based on Eurostat, 2021).

Figure 7 and Figure 8 present the average EU imports of fluorspar at mining stage, by country, for the period 2000-2021. The major EU suppliers of acid-grade fluorspar were China and South Africa; each accounted for 24% of EU's acid-grade fluorspar imports in the period. Mexico, Namibia and Kenya followed with 17%, 13% and 9% of EU's total acid-grade fluorspar imports, respectively. The EU's acid-grade fluorspar suppliers have

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changed significantly over time: while at the beginning of the period, China and South Africa dominated, Mexico was the main supplier at the end of the period. For metallurgical-grade fluorspar, Mexico dominated the supply to the EU over the whole period, accounting for 64% of the supply.

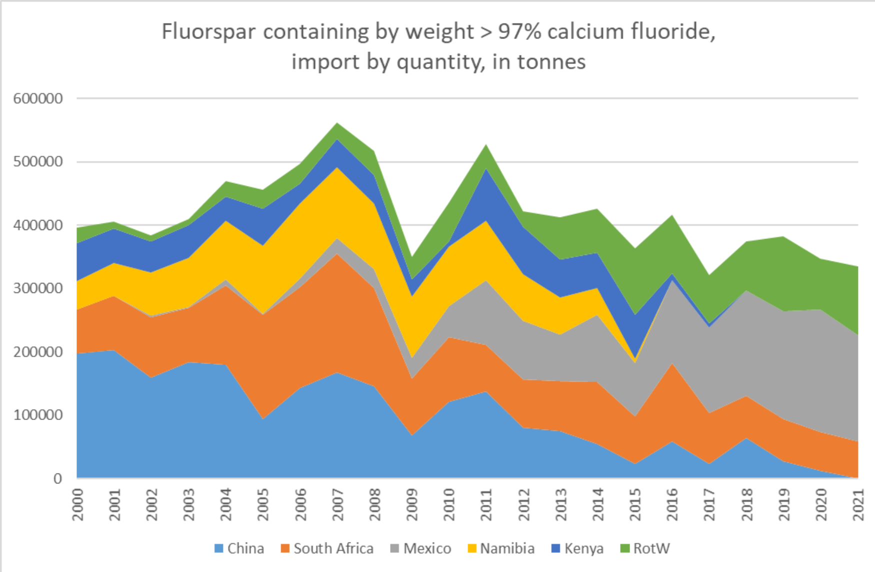

Figure 7 EU imports of acid-grade fluorspar, by country, between 2000-2021 (based on Eurostat, 2021).

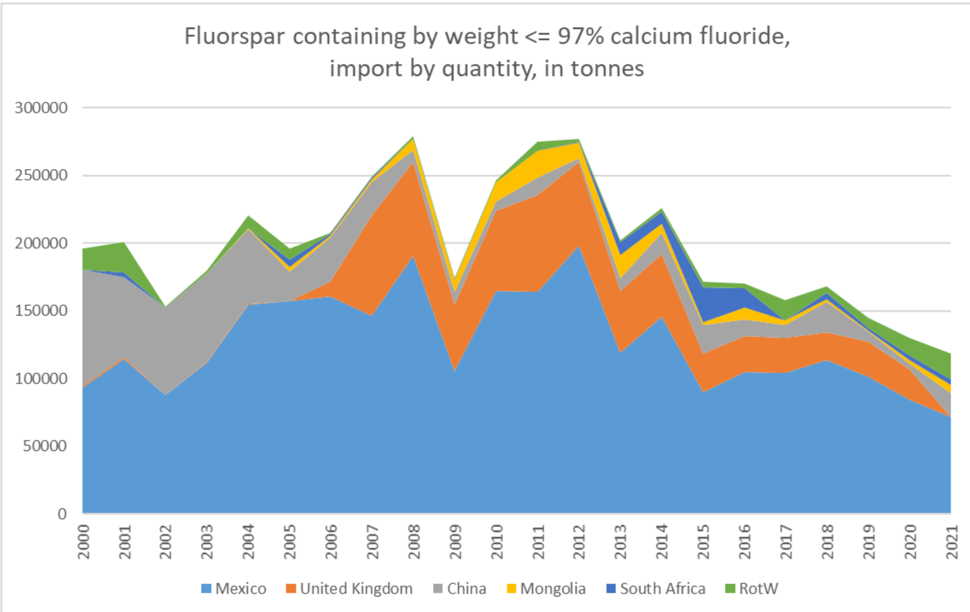

Figure 8 EU imports of metallurgical-grade fluorspar, by country, between 2000-2021 (Eurostat, 2021).

Figure 9, Figure 10 and Figure 11 show the EU trade in fluorspar at processing stage, between 2000 and 2021. For the greatest part of the period, the EU was a net exporter of hydrogen fluoride and synthetic cryolite: the annual EU imports of hydrogen fluoride and synthetic cryolite ranged from 1.9 to 7.8 and 0.7 to 10.2 thousand tonnes, respectively, while the corresponding yearly EU exports were significantly higher (ranging from 3.4 to 25 and 5 to 15.6 thousand tonnes, respectively). The trade-balance of fluoride of aluminium was rather volatile over the period 2000-2021, switching between deficits and surpluses.

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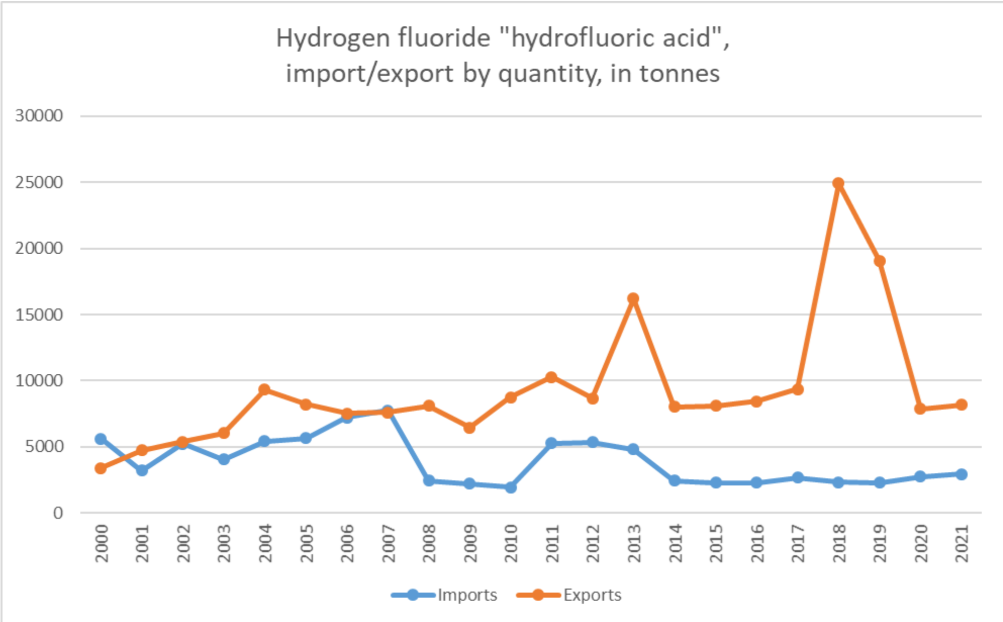

Figure 9 EU trade flows of hydrogen fluoride, from 2000 to 2021 (based on Eurostat, 2021).

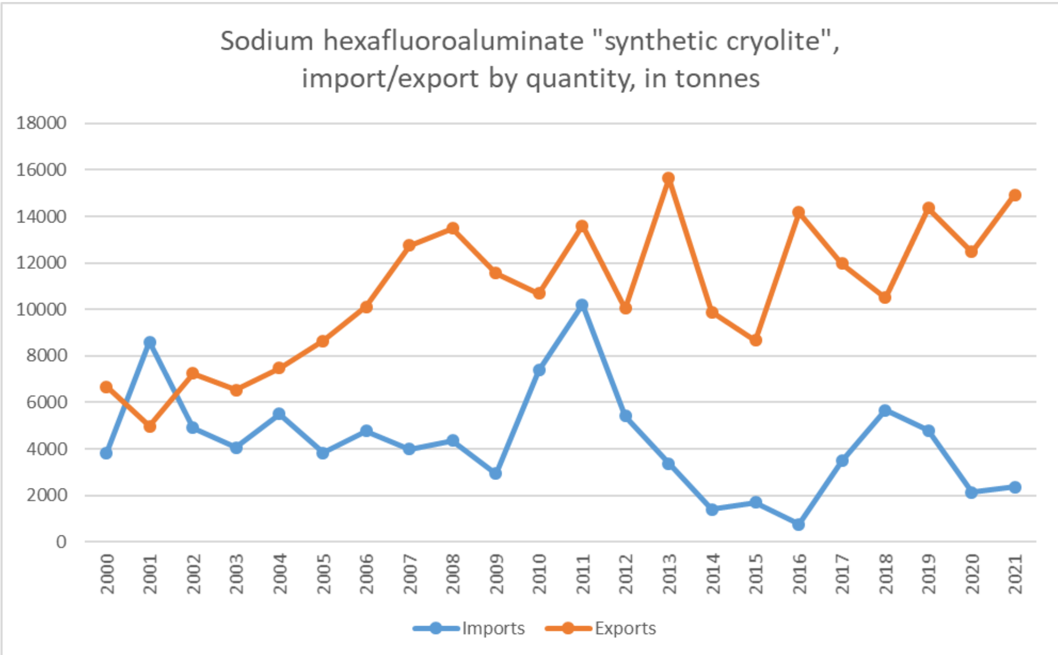

Figure 10 EU trade flows of sodium hexafluoroaluminate ('synthetic cryolite'), from 2000 to 2021 (based on Eurostat, 2021).

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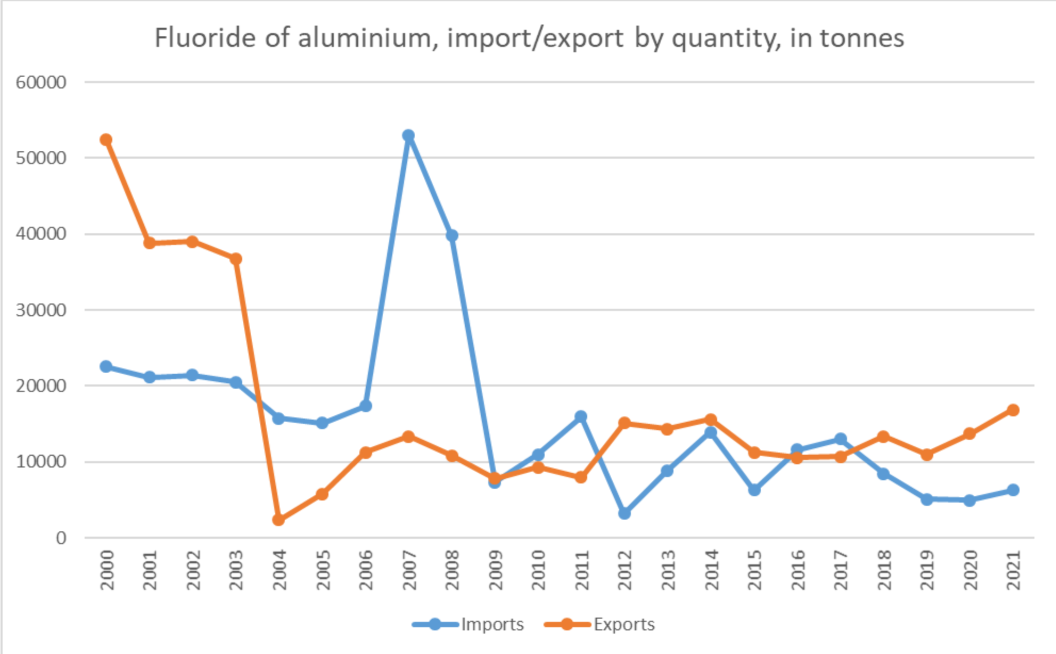

Figure 11 EU trade flows of fluoride of aluminium, from 2000 to 2021 (based on Eurostat, 2021).

Figure 10, Figure 11 and Figure 12 present the average EU imports of fluorspar at processing stage, by country, for the period 2000-2021. The major EU suppliers of hydrogen fluoride were United Kingdom, Kazakhstan and United States contributing 34%, 23% and 13% to this supply, respectively. For synthetic cryolite, the main suppliers were Iceland, China and Norway covering 28%, 18% and 14% of EU's total imports of synthetic cryolite. Supplying 28% and 26% of EU's fluoride-of-aluminium imports, Tunisia and Norway were the main EU-trade partners in this segment.

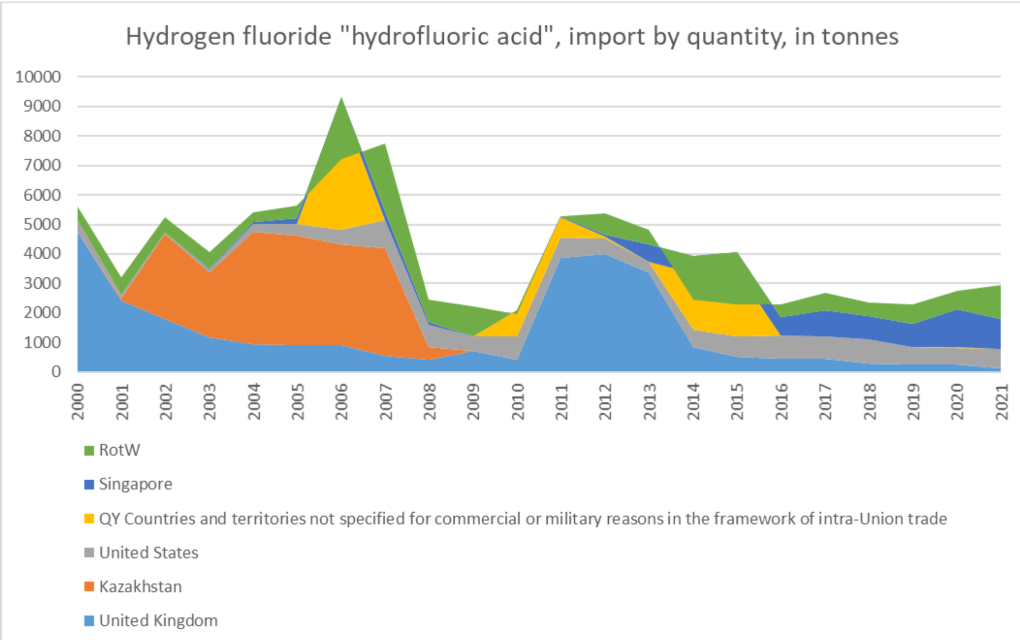

Figure 12 EU imports of hydrogen fluoride, by country, between 2000-2021 (based on Eurostat, 2021).

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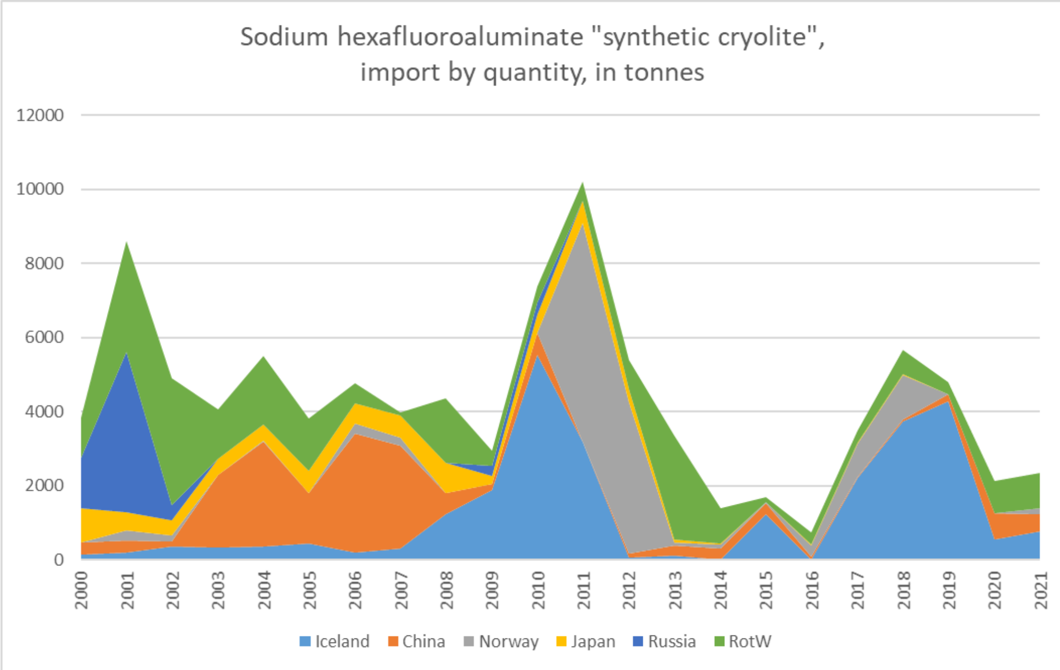

Figure 13 EU imports of sodium hexafluoroaluminate ('synthetic cryolite'), by country, between 2000-2021 (based on Eurostat, 2021).

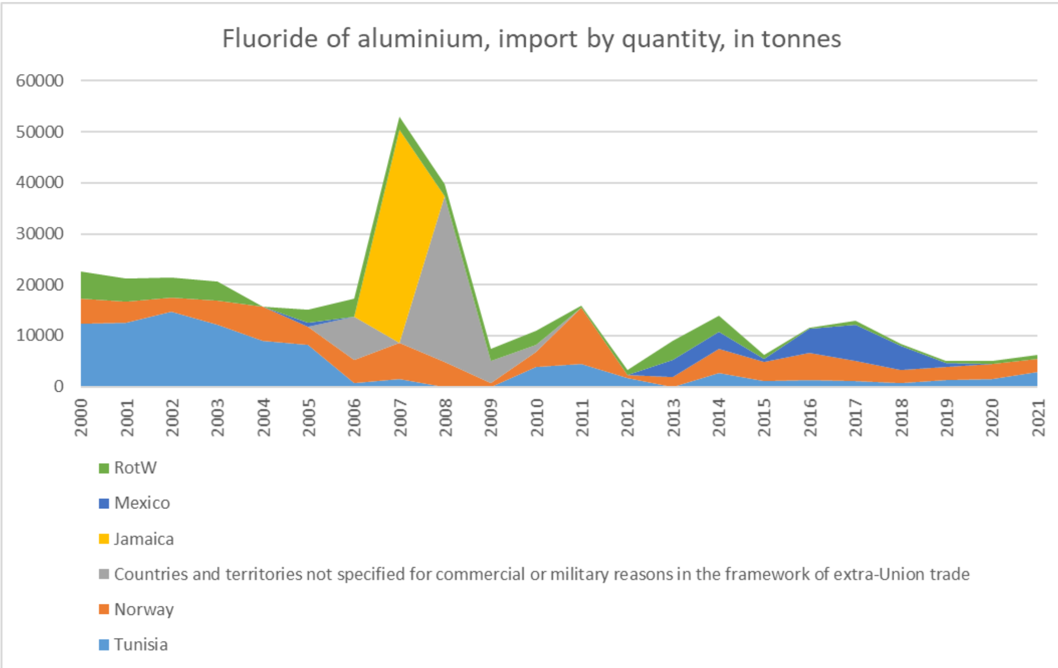

Figure 14 EU imports of fluoride of aluminium, by country, between 2000-2021 (based on Eurostat, 2021).

PRICE AND PRICE VOLATILITY

Prices of fluorspar depend on the fluorspar grade and country of origin, with China, South Africa and Mexico being the biggest exporters (OEC, 2021). The price volatility of the fluorspar market with steep price rises or lows in China or South Africa between 2012 and 2014 has not had a major impact on the prices of imports

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because a major part of fluorspar is traded within fixed price year-long contracts (BGS, 2011). Additionally, the EU has increased fluorspar production to become more independent from market-driven price rises (GMI, 2018).

The price volatility reported for acid grade fluorspar from China was around 20% between the period of January 2016 and December 2020. The value reported for February 2020 and January 2021 was much lower at 5% (DERA, 2021).

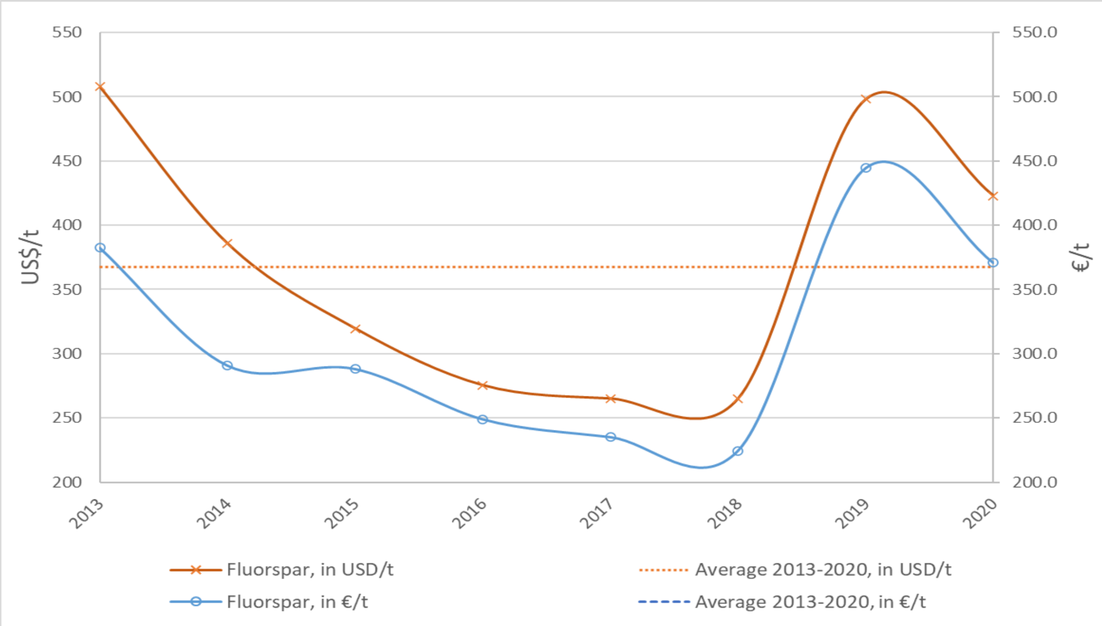

Figure 15 Prices of Chinese acid-grade fluorspar from 2013 to 2020, in US$/kg and €/kg (DERA, 2013-2021)[3]. Dash lines indicate average prices for 2013-2020.

Figure 15 shows the average import price development of Chinese acid grade fluorspar from 2013 to 2020. The price started experiencing a major decrease due to continued surplus in fluorspar stocks and weak markets with Chinese fluorspar being affected most (USGS, 2015). In 2016, the signing of the Kigali Amendment to the Montreal Protocol affected the global fluorochemical market globally and held prices low. The amendment aims to reduce the production and consumption of hydrofluorocarbons which have a high global-warming potential (USGS, 2017). In 2018, the prices for Chinese fluorspar surged most likely due to stricter Chinese environmental protection measures such as environment protection tax and higher transportation costs (Roskill, 2018). However, the price decreased again from 2019 which could be attributed to the fact that global consumption decreased in some downstream applications while new mines continued to ramp up in Canada and South Africa (USGS, 2020).

[3] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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OUTLOOK FOR SUPPLY AND DEMAND

Demand for fluorspar is forecast to grow. No increase is expected for metspar. Demand is likely to decline in the next five to ten years, even though the relevant application areas (steel industry, cement industry, welding industry) will probably grow slightly. The assessment is based on an overall decrease in metspar demand from the steel industry. Growth is attributed to higher demand for acidspar. The fastest growing markets will be battery electrolytes and the electronics industry. However, they will not overtake the acidspar demand for the production of fluorocarbons and chemicals made from them (Roskill, 2020).

No shortage is expected for metspar. There will probably be a market tightness for acidspar in the next ten years. Depending on the supply scenario, capacity is expected to be just sufficient to meet demand if many new fluorspar deposits are opened, or there will already be a shortage in five years if China's fluorspar production slowly declines and few new fluorspar deposits are added (Roskill, 2020).

New fluorspar production capacity in Canada came online in 2018. In 2019, new capacity became available also in South Africa. These new mine production sites will contribute to significant increases of both South African and Canadian production. In Canada, the new mine has an annually acidspar capacity of 185 kt and a metspar capacity of 40 kt, while South Africa is expected to produce 180 kt per year acidspar plus 30 kt per year metspar (Roskill, 2020).

With rising prices, mining in currently unprofitable deposits becomes possible and an incentive is created for further expensive and time-consuming exploration of fluorspar deposits. In the long term, this should also allow relaxation again.

The uncertainties are, e.g.,:

- lack of knowledge on available stocks in Chinese deposits and whether these possibly have lower fluor contents (i.e. lower quality)
- whether there will soon be an upgrading of metspar from Mongolia to higher-quality acidspar in China
- whether large new fluorspar mines will go into production in the next few years
- production of hexafluorosilicic acid (FSA) as an alternative source of fluorine.

DEMAND

GLOBAL & EU DEMAND AND CONSUMPTION

The major part of the global demand of fluorspar comes from the production of hydrofluoric acid (HF) and aluminium fluoride ($AlF3$). The fluorspar market is segmented into four applications: aluminium production, steel production, hydrofluoric acid, and others. Acid grade and metallurgical grade fluorspar together account for a market share over 95% of the global fluorspar market at market stage (Marketwatch Press Release, 2019).

Fluorspar extraction stage EU consumption is presented by HS codes CN 25292200 Fluorspar AG, containing by weight more than 97% of calcium fluoride and CN 25292100 Fluorspar metallurgical grade (containing by

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weight 97% or less of calcium fluoride). Import and export data is extracted from Eurostat Comext (2021). Production data of fluorspar is extracted from WMD (2022).

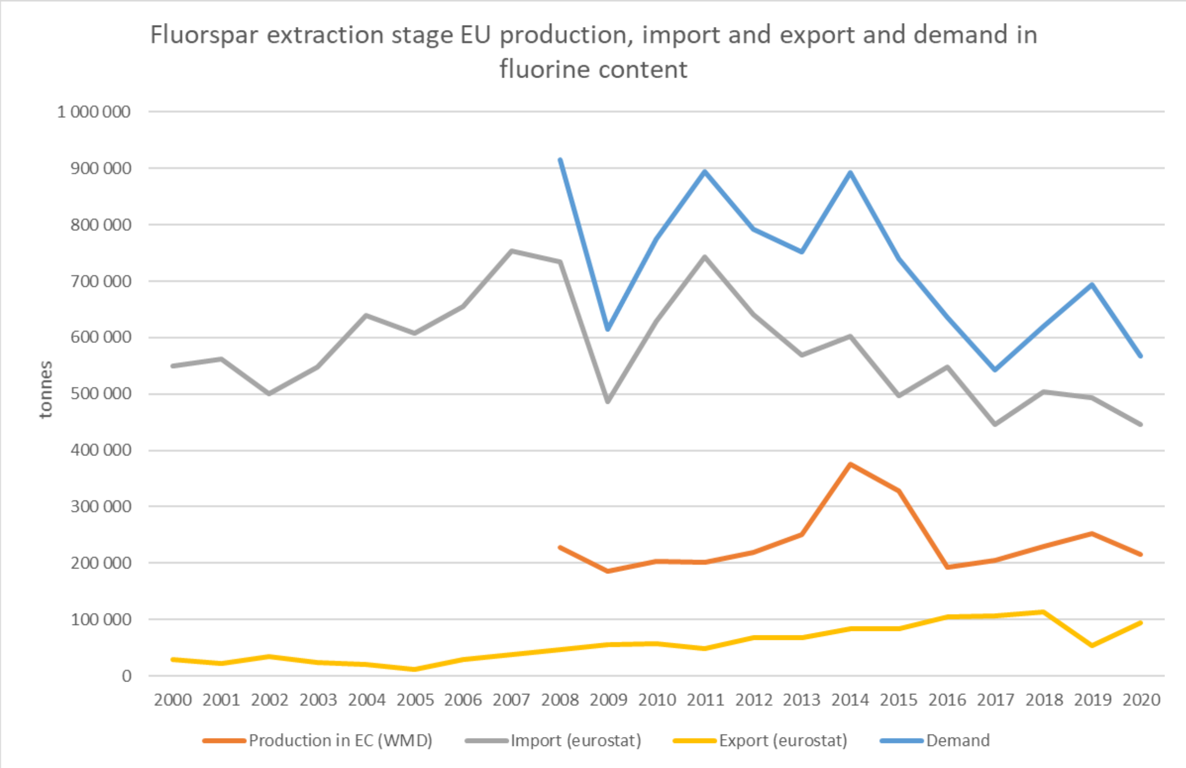

Figure 16. Fluorspar (CN 25292200 Fluorspar AG and CN 25292100 Fluorspar metallurgical grade) extraction stage apparent EU consumption. Production data from WMD (2022) is available for 2008-2020. Consumption is calculated in fluorine content (EU production+import-export).

Based on Eurostat Comext (2021) and WMD (2021) average import reliance of fluorspar at extraction stage is 66.9 % for 2008-2020.

Fluorspar processing stage EU consumption is presented by HS codes CN 28111100 Hydrogen fluoride, CN 28261200 Fluorides; of Aluminium and CN 28263000 Synthetic Cryolite. Import and export data for is extracted from UNComtrade (2021). Production data of is extracted from Eurostat Prodcom (2021) using PRCCODE 20132473 hydrogen fluoride and PRCCODE 20133110 Fluorides; fluorosilicates; fluoroaluminates.

Based on UNComtrade (2021) and Eurostat Prodcom (2021) average import reliance of fluorspar at processing stage is -0.83 % for 2008-2020.

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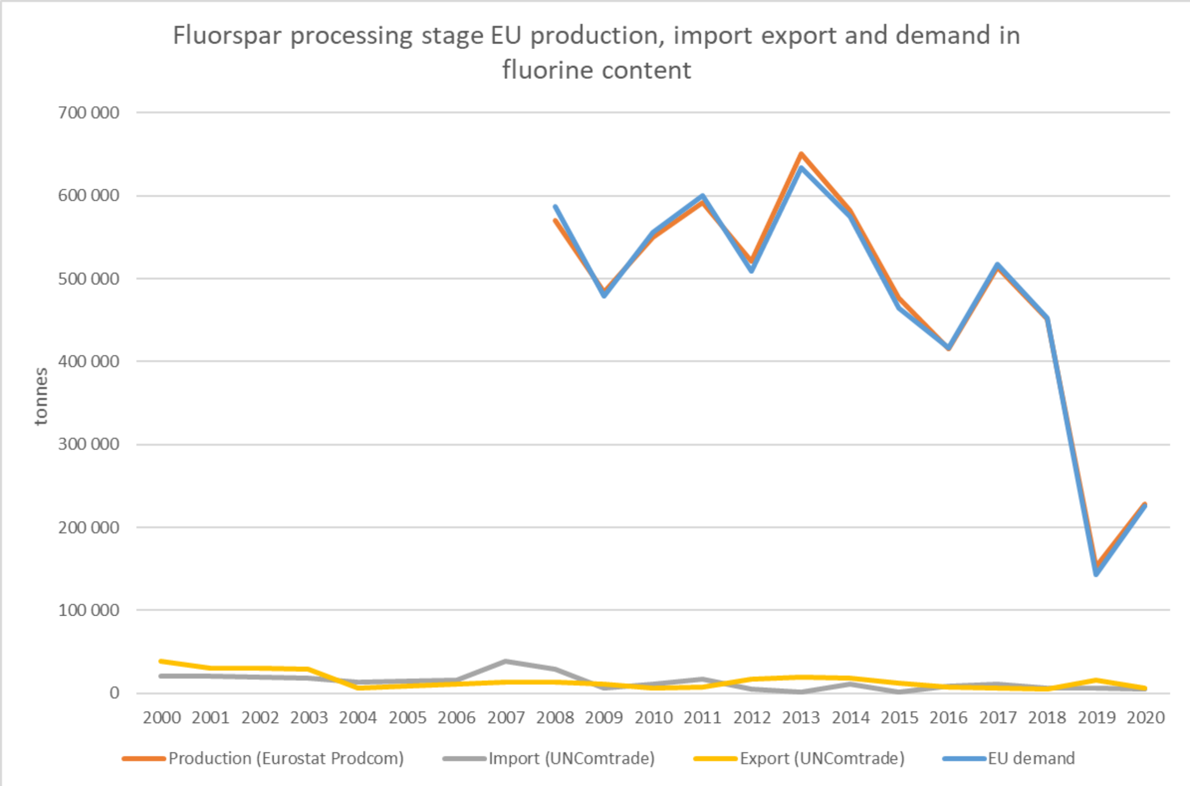

Figure 17. Fluorspar (CN 281111 Hydrogen fluoride, CN 282612 Fluorides; of Aluminium and CN 282630 Synthetic Cryolite) processing stage apparent EU consumption. Production data of Hydrogen fluoride is available for 2008-2020 and of Fluorides; fluorosilicates; fluoroaluminates for 2008-2018 from Eurostat Prodcom (2021). Import data for hydrogen fluoride available for 2000-2014, 2016-2020 and export data for 2000-2009, 2012-2016, 2018-2019 from UNComtrade. Import data for fluorides; of aluminium available for 2000-2012, 2014 and 2016-2020 and export data for 2000-2009, 2012-2015 and 2019. Import and export data for synthetic cryolite available for 2000-2020, except for import data in 2018. Consumption is calculated in fluorine content (EU production+import-export).

EU USES AND END-USES

Fluorspar is used for a wide range of applications.

Figure 3 (right graph) presents the main uses of fluorspar in the EU in the period 2012-2016. To the best of our knowledge, more recent data on the distribution of fluorspar end uses in the EU are not available. Presented numbers were cross-checked for current validity in an expert consultation (SCRREEN workshop 2021).

Beside these uses, the application of fluorine in lithium-ion batteries as additive to the electrolyte (Xu et al. 2021) or cathode material (Hua et al. 2021) is conceivable.

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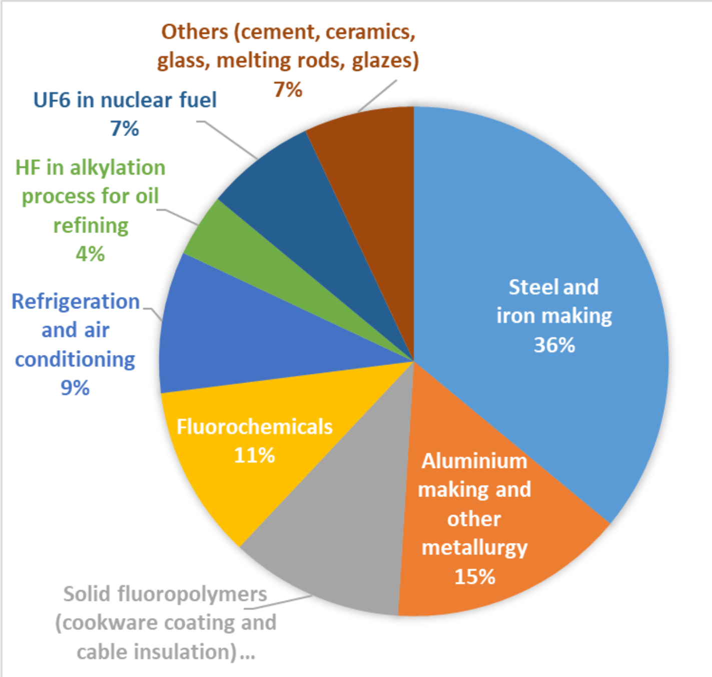

Figure 18 EU end uses of fluorspar (SCRREEN, 2019; Data source: Eurostat, 2019, validated by SCRREEN experts, 2022).

The comparison of the distribution to end uses estimated in the first criticality assessment (European Commission, 2010) and the most up-to-date dataset (SCRREEN, 2019) shows that its importance in metallurgy, for both steel and aluminium, is increasing from 32 % to 51 % of the total fluorspar consumption. Further trends in fluorspar consumption cannot be analysed in detail, as the older graph aggregates the chemical applications like refrigeration, fluoropolymers or fluorochemicals.

Table 5 Fluorspar applications, 2-digit and associated 4-digit NACE sectors, and value added per sector for 2019 (* for 2014) (Eurostat, 2022)

Applications	2-digit NACE sector	Value added of NACE 2 sector (M€)	4-digit CPA
Solid fluoropolymers for cookware coating and cable insulation	C27 - Manufacture of electrical equipment	97,292	C2750- Manufacture of electric domestic appliances; C2740- Manufacture of electric lighting equipment
Refrigeration and air conditioning	C27 - Manufacture of electrical equipment	97,292	C2750- Manufacture of electric domestic appliances; C2819- Manufacture of non-domestic cooling and ventilation equipment;
Refrigeration and air conditioning	C29 - Manufacture of motor vehicles, trailers and semi-trailers	234,398	C2920- Manufacture of electrical and electronic equipment for motor vehicles
Steel and iron making	C24 - Manufacture of basic metals	63,700	C2410- Manufacture of basic iron and steel and of ferro-alloys

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Fluorochemicals	C20 - Manufacture of chemicals and chemical products	117,150*	C2011- Manufacture of other organic basic chemicals; C2021- Manufacture of pesticides and other agrochemical products; C2029- Manufacture of other chemical products n.e.c.
UF6 in nuclear uranium fuel	C24 - Manufacture of basic metals	63,700	C2420- Processing of nuclear fuel
HF in alkylation process for oil refining	C19 - Manufacture of coke and refined petroleum products	24,896	C1920 - Manufacture of refined petroleum products
Aluminium making and other metallurgy	C24 - Manufacture of basic metals	63,700	C2420- Aluminium production; C2029- Manufacture of other chemical products n.e.c.

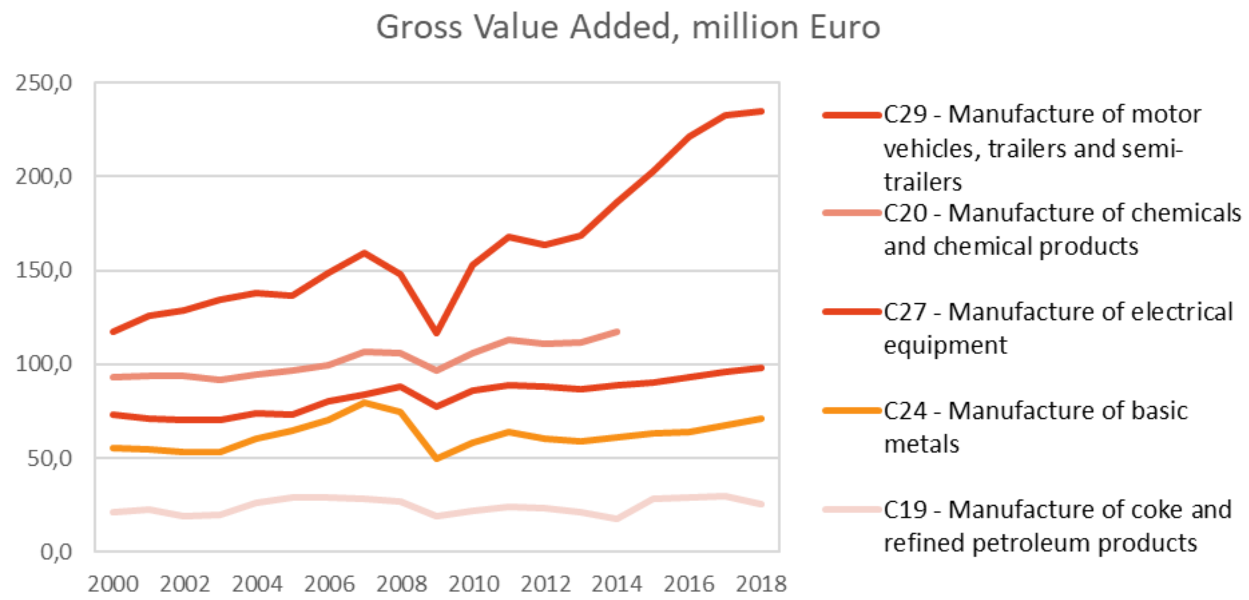

Figure 19 Value added per 2-digit NACE sector over time (Eurostat, 2021)

APPLICATIONS OF FLUORSPAR IN THE EU:

METALLURGY

Fluorspar is used as a flux in iron and steel making furnaces, where it brings various benefits to the smelting process (Bide, 2011). Additionally, AlF_3 and cryolite is used for aluminium processing and hydrogen fluoride (HF) for pickling/etching applications.

REFRIGERATION AND AIR CONDITIONING

Fluorochemicals are used for the production of refrigerants for refrigeration and air conditioning in automobiles or other vehicles (e.g. military) and heat-pumps.

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SOLID FLUOROPOLYMERS

Solid fluoropolymers are used for non-stick cookware coating, cable insulation in household electrical appliances, lighting industry, telecommunications, aeronautics, nuclear, military, fuel-cells as well as for membranes.

FLUOROCHEMICALS

Fluorochemicals are used in the form of inorganic fluorine compounds, as well as fluoroaromatics in pharmaceuticals (e.g. anaesthetics) and agrochemicals industry. Hydrofluorocarbons are used as aerosol can propellants, blowing agent for foam and for fire extinguishers (Bide, 2011).

NUCLEAR URANIUM FUEL

Uranium hexafluoride (UF6) is used as a nuclear uranium fuel.

OIL REFINING

Hydrogen Fluoride (HF) is used as a catalyst in the alkylation process for oil refining.

GLASS AND CERAMIC INDUSTRY

Fluorspar is used in the glass and ceramic industry to produce e.g. lenses, high quality optics, opal glass or opaque enamels (Bide, 2011).

SUBSTITUTION

Table 6. Uses and possible substitutes

Use	Percentage*	Substitutes	Sub share	Cost	Performance
Steel and iron making	36%	Calcium aluminate	25%	Slightly higher costs (up to 2 times)	Reduced
	36%	Aluminium smelting dross	25%	Slightly higher costs (up to 2 times)	Reduced
Solid fluoropolymers (cookware coating and cable insulation)	11%	Plastics	5%	Similar or lower costs	Reduced
	11%	Stainless steel	5%	Similar or lower costs	Reduced
	11%	Ceramics	5%	Slightly higher costs (up to 2 times)	Reduced
	11%	Aluminium	2%	Similar or lower costs	Reduced

*Estimated EU27 end use shares fluorospar, SCRREEN, 2019; Data source: Eurostat, 2019, validated by SCRREEN experts, 2022).

METALLURGY

In the iron and steel making sector substitutes exist but come with a loss of performance. Possible alternatives are calcium aluminate/chloride, aluminium smelting dross, borax, iron oxides, manganese ore, silica sand and

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titanium oxide (Tercero Espinoza, 2015). In electrolysis-based aluminium production, fluorspar cannot be substituted, but fluorspar-free carbothermic reduction processes are conceivable (Tercero Espinoza, 2015).

REFRIGERATION AND AIR CONDITIONING

There is a major push to substitute fluorine used in many industries, especially in the air conditioning and refrigerator sector, for more environmentally friendly options (Bide, 2011). These alternative materials include hydrocarbons such as propane. Due to their low global warming potential, Hydrofluoroolefins (HFO-1234ze, HFO-1234yf, HFO-1233zd) and mixtures based on HFOs are the most likely replacement for fluorocarbons (The Chemours Company, 2016).

SOLID FLUOROPOLYMERS

Alternative materials for solid fluoropolymers include plastics, stainless steel, ceramics and aluminium (The Chemours Company, 2016). These alternatives could show lower performance.

OIL REFINING

HF builds hydrofluoric acid when it is in solution. The acid produced in phosphate plants can substitute fluorspar for acid production (SCRREEN 2021).

SUPPLY

EU SUPPLY CHAIN

The flows of fluorspar through the EU economy are demonstrated in Figure 20. The EU supply chain of fluorspar includes exploration, extraction, processing, manufacturing.

Exploration: Occurrences in the EU have been detected in several countries in the EU

Extraction stage: The EU remained very dependent on imports of fluorspar at mine stage, with an import reliance of >70% in 2019. The EU production of primary fluorspar (CaF_2 content) over the period 2016-2019 ranged between 446 kt and 547 kt, while the production in the same period ranged between 193 kt and 253 kt. The amount of EU exports in the period 2016-2020 ranged between 53 kt and 106 kt. There is no production of metallurgical grade fluorspar in the EU. The EU production of fluorspar is taking place mainly in Spain, Germany and Bulgaria (WMD, 2019). There was some production in France and in Italy, but both activities ceased in 2006. Fluorspar mine in Bulgaria was closed in early 2016, taking approximatively 30 kt per year of EU production capacity out of the market. This has an impact on the EU import reliance (CRM Alliance, 2016).

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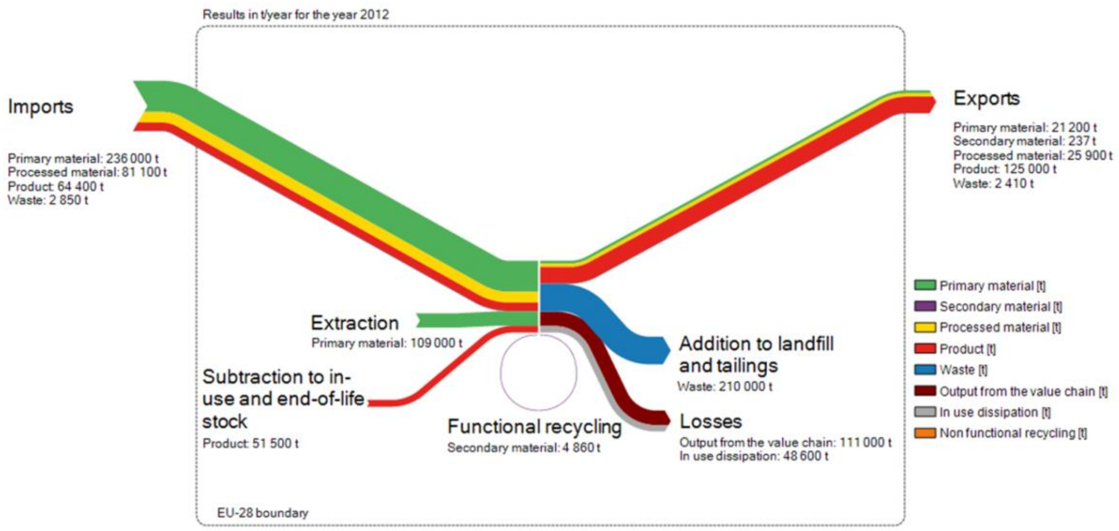

Figure 20 Simplified Material System Analysis diagram of fluorspar, reference year 2012, EU27 and the UK (BioIntelligence, 2015)

SUPPLY FROM PRIMARY MATERIALS

GEOLOGY, RESOURCES AND RESERVES OF FLUORSPAR

GEOLOGICAL OCCURRENCE

Fluorspar is the main commodity for fluorine. Fluorspar is the commercial name for fluorite (CaF_2), a relatively common mineral in highly fractioned magmatic rocks and hydrothermal deposits. Most fluorite occurs as vein fillings in rocks that have been hydrothermally altered (BGS, 2011). Magmatic brines and brines from deep sedimentary basins that have high concentrations of dissolved fluoride are the mineralizing fluids for various types of hydrothermal fluorspar deposits. These types of deposits are often associated with Missisippi Valley-Type (MVT) deposits with Pb-Zn-F-Ba and accompanied by other metallic ores such as sulfides of tin, silver, lead, zinc and copper. Hydrothermal fluorite deposits are usually associated with carbonatites (e.g. the Fission deposit in Ontario, Canada, the Okorusu deposit in Namibia, the Amba Dongar deposit in India), alkaline intrusions (e.g. the Yermakovskoye deposit in Buryatiya Republic, Russia, the St. Lawrence district in Newfoundland, Canada), and epithermal volcanic activity (e.g. in Mexico and Kenya). Sedimentary-derived fluorite has been described in phosphorite rocks in which 2 to 4 wight % fluorine concentrations have been encountered. Phosphorite deposits can exceed 1 billion metric tonnes of ore (Hayes et al. 2017). Fluorite is also present as fillings in fractures in limestone and dolomite. Residual fluorspar deposits are found in weathered zones and soil (BGS, 2011; Hayes et al. 2017).

Depending on type of the deposit, commercial fluorspar concentrate contains mineral impurities such as calcite, dolomite, quartz, chalcedony, barite, celestite, various sulphides, phosphates, and others. The textures and mineralogy of ore determine the type of the concentrate that can be produced. Commercial fluorspar products are then subdivided into ceramic, metallurgical and acid grades (Simandl 2009).

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GLOBAL RESOURCES AND RESERVES:

World known reserves of fluorspar are estimated at around 320 million tonnes of CaF_2 (USGS, 2022). Mexico has the world's largest fluorspar reserves, followed by China and South Africa (Table 1). The world reserves of fluorspar estimated in 2018 according to infomed.com are presented in Figure 2.

Table 7 Global reserves of fluorspar (USGS, 2022)

Country	Fluorspar Reserves (million tonnes CaF2)
Argentina	NA
Brazil	1.5
China	42
Germany	NA
Iran	3.4
Kenya	2
Mexico	68
Mongolia	22
Morocco	0.46
South Africa	41
Spain	6
Thailand	3.6
United Kingdom	4
United States	4
Vietnam	5
Other countries	110

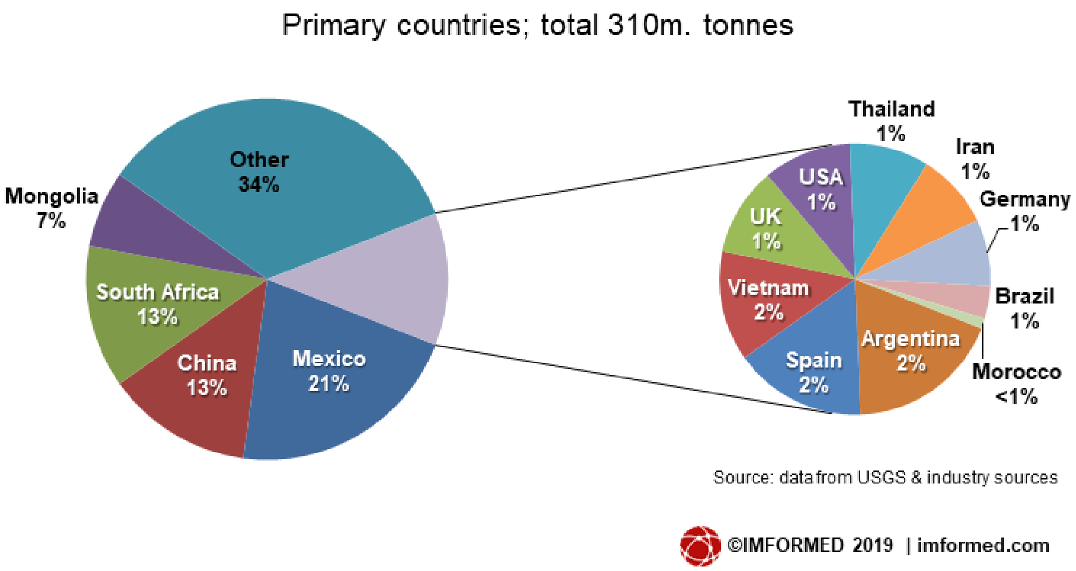

Figure 21 World reserves of fluorspar estimated in 2018 (informed.com).

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EU RESOURCES AND RESERVES

Resource data for some countries in Europe are available at Minerals4EU (2019))87 but cannot be summed as they are partial and they do not use the same reporting code (Table 2).

Table 8 Resource data for the EU compiled in the European Minerals Yearbook (Minerals4EU, 2019)

Country	Reporting code	Quantity	Unit	Grade	Code Resource Type
Spain	Adapted version of the USGS Circular 831 of 1980	4,794	kt	-	Measured
France	-	9.6	Mt (CaF2 content)	-	Historic Resource Estimates
UK	-	25	Mt (CaF2 content)	-	Historic Resource Estimates
Sweden	JORC	25	Mt	10.28%	Indicated
Norway	JORC	4	Mt	24.6%	Inferred
Poland	Nat. rep. code	0.54	Mt	-	C2+D
Ukraine	Russian Classification	18,500	kt	-	P1
Hungary	Russian Classification	?	Million	2.9t/m3	-
Serbia	-	0.8	Mt	27.01%	Historic Resource
Czech	Nat. rep. code	2,033	kt	-	Potentiall

The USGS reported EU reserves of fluorspar in Germany and Spain (Table 52). Spain has 262 occurrences of fluorspar in Asturias, Andalusia, Catalonia, Madrid, Aragón, Vizcaya, Segovia, Guadalajara, and Galicia, hosting in total 5 million tonnes of reserves (Informed, 2019).

SCRREEN88 listed occurrences of fluorspar in the following EU countries:

- France: Numerous occurrences were reported, with an estimate resources at about 7.3 Mt.
- Germany : Several deposits and occurrences are known, with fluorite resources estimated at 0.92 Mt
- Italy: Approximately 35 Mt of fluorite resources were reported. Italy had fluorspar production until 2006. There is mainly only mineralogical interests for fluorspar in Italy.
- Poland: resources of fluorspar were estimated at 0.54 Mt
- Spain: resources estimated at 3.8 Mt. Spain has several tens of known fluorite deposits in several areas, the most important one Asturias in northern Spain.
- Sweden: the total estimated resource includes 25.0 Mt of Indicated resources and 2.7 Mt of Inferred resources. There are other three small historic closed mines with no resource estimates available.
- Occurrences were also reported for Austria, Czechia, Hungary, and Ireland, with no quantitative resource information. However, the resources in these countries are known to be uneconomic.

WORLD AND EU MINE PRODUCTION

After extraction, fluorspar ore is directly transformed into fluorspar acid grade (AG, 97% of CaF2 contained) and metallurgical grade (MG, 84% of CaF2 contained). The world annual production of fluorspar ores in

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average between 2012 and 2016 is around 6,400 ktonnes of CaF2 content, extracted mainly in China and Mexico. Global production in 2020 was 7.6 Mt. Main producing countries were China (57%), Mexico (16%), Mongolia (9.5%), South Africa (4.2%) and Vietnam (3.2%) (USGS 2021). In 2020, China's mine production was the world's largest, with 4.3 million tonnes of fluorspar. Second largest was Mexico with 1200 tonnes and the third was Mongolia with 720 tonnes (Statista 2022) ([1]https://www.statista.com/statistics/1051717/global-fluorspar-production-by-country/). In Vietnam, the Nui Phao open pit mine is projected to provide nearly 214,000 metric tonnes fluorspar per year for 20 years (Hayes et al., 2017).

In Morocco, GFL GM Fluorspar SA (Taourirt province) fluorspar production has been expanding, with the open pit mine and beneficiation plant operational since 2018 with a capacity of 40,000 tpa acidspar, which is further planned to be increased to 60,000 tpa ([4]http://imformed.com/new-fluorspar-source-for-european-markets/).

Fluorspar extraction was taking place only in 3 EU countries in 2020: Spain was the larger producer with about 185,000 metric tonnes, followed by Germany (65,000 tonnes) and Italy (50,000). A small production in Bulgaria (4400 tonnes) was interrupted after 2016.

The global fluorspar production by country since 1984 according to WMD and since 2000 according to USGS can be seen in Figures 22 and 23 respectively (WMD, since 1984; USGS, since 2000). China, Mexico, Mongolia, South Africa, Spain and Morocco consist the major producers continuously the last two decades.

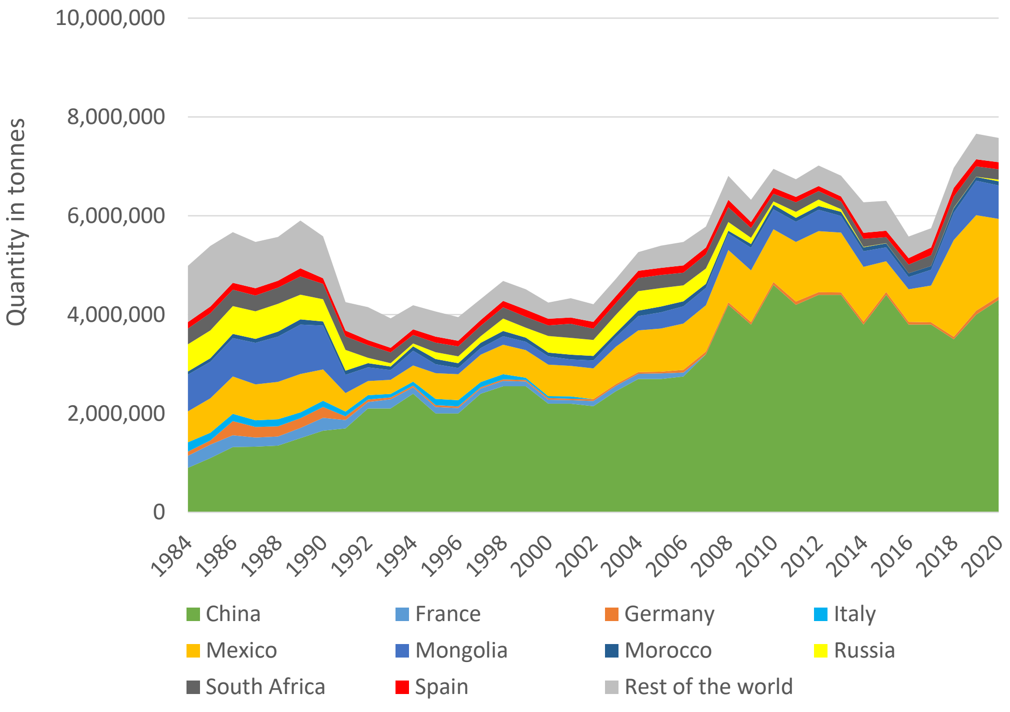

Figure 22 Global fluorspar production by country since 1984 (WMD, since 1984).

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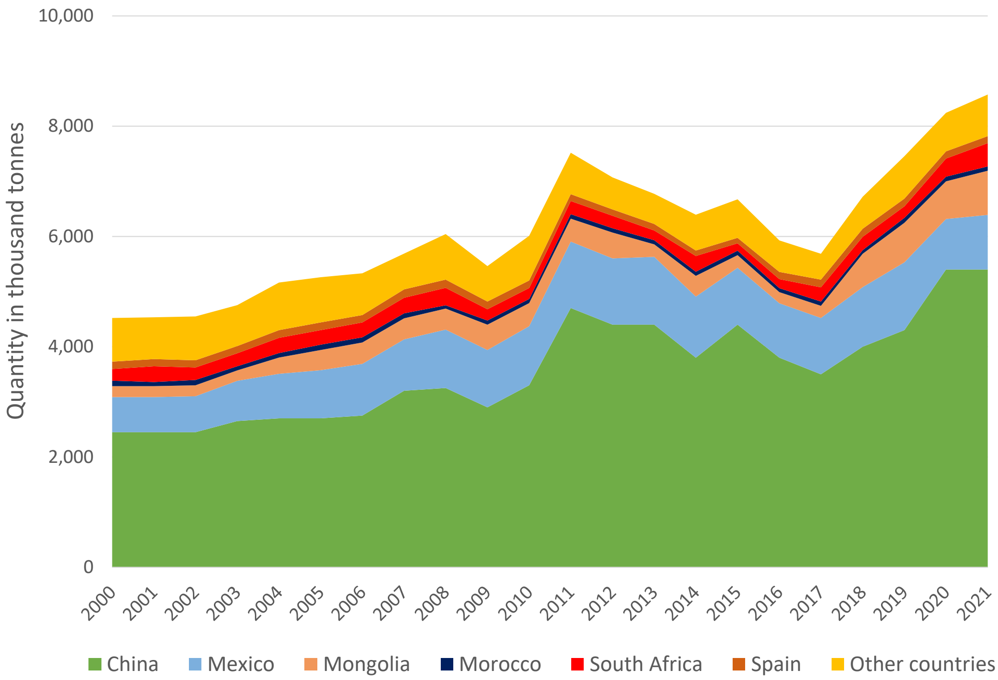

Figure 23 Global fluorspar production by country since 1984 (USGS, since 2000).

Table 9 fluorspar production in 2019 per country (http://www.euromines.org/mining-europe/production-mineral; World Mining Data 2020)

Country	Production 2019 (t)	Country	Production 2019 (t)
EUROPE		**ASIA**	
Bulgaria	4400	Afghanistan	50000
France	40000	China	4000000
Germany	79959	India	1315
Italy	10449	Iran	54824
Romania	15000	Kazakgstan	70000
Russia (European part)	800	South Korea	6900
Spain	170000	Kyrgyzstan	2656
United Kingdom	11000	Mongolia	699400
AFRICA		Pakistan	4208
Egypt	1000	Russia (Asian part)	4000
Kenya	6945	Thailand	17747
Morocco	73244	Turkey	14400
Namibia	70414	Uzbekistan	80000
South Africa	210000	Vietnam	238003
Sudan	950		
Tunisia	950		
AMERICA			
Argentina	1500		
Brazil	15000		
Canada	80000		

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Colombia	46		
Mexico	1931532		
United States	7000		

OUTLOOK FOR SUPPLY

Global mine production increased in 2021 due to the continued ramp up of production at mines in Canada, Mongolia, and South Africa. Globally, several projects to produce HF from FSA also continued to progress (USGS, 2022). New mining and fluorspar processing projects have been recently developed in Mongolia. Gobishoo Company commissioned its 35,000 tonnes/year acidspar plant, which consumes a raw feed of 100,000 tonnes of fluorspar ore. The company mines and processes at the same location, at the Shine Us mine in Dundgobi province (Informed, 2021).

SUPPLY FROM SECONDARY MATERIALS/RECYCLING

Fluorspar is recycled only to a minor extent since its uses are dissipative, or recycling is not practicable (Sundqvist Oeqvist, Pr. Lena et al. ,2018).

POST-CONSUMER RECYCLING (OLD SCRAP)

Fluorspar is generally not recovered from manufactured products such as flint glass, enamels, and fibreglass insulation, since it is highly dispersed in those applications. Limited recycling of fluorspar from end of life products is theoretically feasible. However, there is no information of any recycling operations ongoing in the EU and worldwide (Sundqvist Oeqvist, Pr. Lena et al., 2018). Fluorspar is practically not recyclable, therefore fluorspar contained in the waste mainly ends up in landfills (European Commission, 2014). According to the MSA study of fluorspar, the end of life recycling input rate is 1%. (Bio Intelligence Service, 2015). Table 4 shows the quantity of flows relevant to the end-of-life recycling input rate of fluorspar in the EU. The data refers to 2012.

Table 10 Material flows relevant to the EOL-RIR of Fluorspar

MSA Flow	Value (t)
B.1.1 Production of primary material as main product in EU sent to processing in EU	87312
B.1.2 Production of primary material as by product in EU sent to processing in EU	0
C.1.3 Imports to EU of primary material	236303
C.1.4 Imports to EU of secondary material	0
D.1.3 Imports to EU of processed material	81142
E.1.6 Products at end of life in EU collected for treatment	130813
F.1.1 Exports from EU of manufactured products at end-of-life	193
F.1.2 Imports to EU of manufactured products at end-of-life	2847
G.1.1 Production of secondary material from post consumer functional recycling in EU sent to processing in EU	0
G.1.2 Production of secondary material from post consumer functional recycling in EU sent to manufacture in EU	4861

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INDUSTRIAL RECYCLING (NEW SCRAP)

Although fluorspar itself is not recyclable, a few thousand tons of synthetic fluorspar are recovered each year during the uranium enrichment (as well as stainless steel pickling and petroleum alkylation). In the case of aluminium producers, hydrofluoric acid (HF) and fluorides are recovered during the smelting operations (USGS, 2015). In the air-conditioning and refrigeration sector, close to 60-70% of the fluorochemicals are recycled (The Chemours Company, 2016).

PROCESSING OF FLUORSPAR

The acid grade (AG) and metallurgical grade (MG) fluorspar are processed into hydrofluoric acid (HF), cryolite (Na3AlF6) and aluminium fluoride (AlF3).

Fluorspar MG is also used in iron and steel making, but is not incorporated into the iron and steel products. The processed material HF is converted into semi-finished products such as fluorocarbons, fluoropolymers, fluoroaromatics and uranium hexafluoride (UF6, used in nuclear energy production), or it is directly converted into finished products such as inorganic fluorine compounds. HF is also used for etching and pickling of metals and for alkylation process in oil refining, however, fluorine is not transferred in the final products for these applications. In the same way, cryolite and aluminium fluoride are used for aluminium processing, but are not incorporated in aluminium alloys. Fluorocarbons, fluoropolymers and fluoroaromatics are used in finished products in various applications such as cable insulation, fire protection, refrigerants, pharmaceuticals, etc.

There is no official data on the global supply of processed fluorspar, or on its components: of global hydrofluoric acid (HF), cryolite (Na3AlF6) and aluminium fluoride (AlF3). Based on the export quantity of processed fluorspar reported by UNComtrade (2019), the average annual processed fluorspar in the period 2012-2016 was 839 kt per year of fluorine content. As shown in Figure 24 the production of processed fluorspar is concentrated mainly in China (34%) and Mexico (16%).

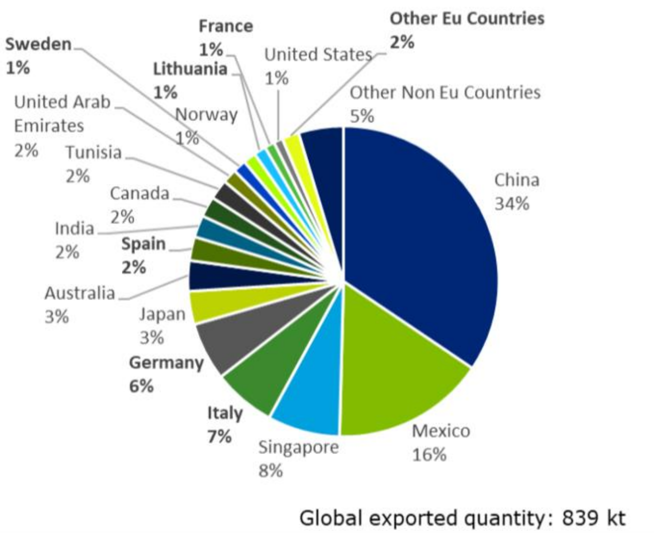

Figure 24 Global and EU production of fluorspar products, in fluorine content. Average for the period 2012-2016 (Comtrade, 2019)

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OTHER CONSIDERATIONS

HEALTH AND SAFETY ISSUES

Artisanal and small-scale mining represent a large share of global production (e.g. in Mongolia; Barreto et al., 2018), which implies health problems due to fluoride exposure and occupational safety issues (German Environment Agency, 2020).

Fluoride intake has both beneficial and negative effects: it reduces the incidence of dental caries but may cause tooth enamel and skeletal fluorosis in case of prolonged exposure to high concentrations (WHO, 2019).

Occupational health limits for fluorspar can be found in the GESTIS Substance database[4]. In addition, fluorspar is included under the German regulation of accident insurers[5] for the use of respiratory protective equipment.

ENVIRONMENTAL ISSUES

There is limited literature on the environmental impacts of fluorspar extraction and concentration in a life cycle perspective. In their LCA study with case application to the Lujar mine (Spain), (Lai et al. 2021) report that the carbon footprint associated with the production of 1 tonne of fluorspar concentrate (79.2 % CaF_2) amounts to 174 kg CO2-eq. The main contributions to impacts are due to diesel consumption by the machinery and the on-site generators in the mining and loading/hauling steps (main contribution regarding 11 impact categories out of 16), and to the mine infrastructure/equipment (main contribution regarding 4 impact categories).

NORMATIVE REQUIREMENTS RELATED TO THE USE AND PROCESSING OF FLUORSPAR

No information could be identified on this specific aspect.

SOCIO-ECONOMIC AND ETHICAL ISSUES

ECONOMIC IMPORTANCE OF FLUORSPAR PRODUCT EXPORTS FOR EXPORTING COUNTRIES

Mongolia is the only country with more than 0.1 % share of fluorspar product exports in their total export values.

Table 11: Countries with highest economic shares of fluorspar product exports in their total exports

Country	Export value (USD)	Share in total exports (%)
Mongolia	156,322,974	2.1

Source: COMTRADE (2022), based on data for 2020

[4] See https://gestis-database.dguv.de/data?name=003620
[5]See https://publikationen.dguv.de/regelwerk/dguv-regeln/1011/benutzung-von-atemschutzgeraeten

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SOCIAL AND ETHICAL ASPECTS

The focus of reports is on Mexico, Mongolia, China and Vietnam.

Heavy metals, including arsenic, mercury, cadmium and lead, as a product of the metallurgical and foundry industry, were detected in children of the city of San Luis Potosí from the Las Cuevas Mine in the State of San Luis Potosí, the largest fluorite mine in Mexico. Water is contaminated with fluorine and arsenic, product of the extensive drilling of water wells and the transfer of contaminants from the mining and metallurgical industry. The air was found to be contaminated with heavy metals of mining and metallurgy and hydrocarbons in urban and rural areas (Silva und Jiménez, 2020).

Around Erdenetsagaan, one of Mongolia's burgeoning mining hotspots, mines for fluorspar, tungsten, and other commodities have sprung up around the region, with companies submitting permanently new exploration requests. Many of Erdenetsagaan's residents have yet to benefit from this newfound economic growth. Instead, increased mineral extraction has threatened their lives, livelihoods and culture. Mining not only erodes the region's grassland ecosystems, but residents also suspect that it leaches toxic contaminants into the groundwater, poisoning communities' already limited water supply. Natural springs that once delivered clean drinking water to herders' animals are also running dry as mining companies deplete local streams. Residents have also documented two (oil and) fluorspar mining companies' consistent illegal actions, but officials have yet to revoke the corporations' licenses. And community members' repeated requests to access basic environmental information, including environmental impact assessments, water and land use permits, reports detailing companies' violations of mining regulations and public consultation notices, continue to go unanswered (Moses, 2020).

As regards, child labor in minining, Mongolia made minimal advancement in efforts to eliminate the worst forms of child activity. This includes the fluorspar industry, as shown in the report "FINDINGS ON THE WORST FORMS OF CHILD LABOR".

Shizhuyuan Mine is the largest polymetallic tungsten fluorite deposit in China. In the Suxian District, South China, the Shizhuyuan mine sites metal have released toxic substances into the environment and therefore negatively impact the health of residents in nearby regions (Song et al., 2013; Ding et al., 2016; Chen et al., 2018). Song et al (2013) investigated whether there was excess disease mortality in populations in the vicinity of the mining area in Suxian District. The spatial distribution of metal mining including fluorspar and related activities from 1985 to 2012, which was derived from remote sensing imagery, was overlapped with disease mortality data. Three hotspot areas with high disease mortality were identified around the Shizhuyuan mine sites, i.e., the Dengjiatang metal smelting sites, and the Xianxichong mine sites. Disease mortality decreased with the distance to the mining and smelting areas. Population exposure to pollution was estimated on the basis of distance from town of residence to pollution source. The risk of dying according to disease mortality rates was analyzed within 7–25 km buffers. The results suggested that there was a close relationship between the risk of disease mortality and proximity to the Suxian District mining industries Song et al (2013). These associations were dependent on the type and scale of mining activities, the area influenced by mining. Heavy metal contents were highest in 1 km buffer zone and decreased with increasing distance from the mining area. The largest decrease in heavy metal concentrations was in 2 km buffer zone. Perennial wind promotes the

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transport of heavy metals in downwind direction. The spatial extent of the influence of the river on Pb, Zn and Cu in the soil was 800 m (Ding et al., 2016). Approximately 82.9 % of Suxian is at a strong risk level, demonstrating serious soil pollution. The quite strong risk region with the portion of 18.33 % of total area is primarily concentrated around the large Polymetallic mine. More than half of the soil in Suxian presents a strong mercury risk level, and the primary strong ecological risk and quite strong ecological risk townships were identified as well (Chen, Y. et al., 2018).

Nui Phao mine in Thai Nguyen Province, Vietnam, is the second-largest tungsten-fluorspar (W) open-pit mine in the world, but the level of environmental, health and social impacts is not well known. In 2016, Vietnam's Ministry of Natural Resources and Environment conducted a comprehensive inspection of the Nui Phao mine in Thai Nguyen Province, the second-largest tungsten-fluorspar (W) open-pit mine in the world, after receiving complaints from local people about the project's environmental impacts. Between 2013 and 2016, the local government in Ha Thuong Commune has received many complaints from local people living in villages near the project who said they are directly affected by the smell, noise and wastewater from Nui Phao. The Nui Phao Mining Company Limited was believed to use more than 20 different chemicals to process ore, including toxic substances. Hence, Nui Phao Mining Company was asked to install an automatic wastewater monitoring system (Dao, 2016). The fluctuation of the ground water level is significantly influenced by the seasons, hence monitoring pro-gramme has been continued to better understand the movements in the water table and how it is replenished in order to manage the adverse impacts of water extraction on the community around the pit (Masan Resources, 2015; Wessex Institute, 2018). In 2018 Masan Resources conducted numerous collective and collaborative efforts to address issues pertaining to materials management, wastewater management and rehabilitation works (Wadlow, 2019).

Supporting the community and environment in the form of an extensive corporate social responsibility programme of Masan's work has been issued. Investment in neighbouring communities of the mine lays the foundations for long-term development and prosperity. Since the early stages of our operations, Masan Resources has striven to work with our nearby communities to help them develop through participation in the Resettlement Action Plan, yearly community development plans, and other environmental and social initiatives. Masan started identifying the main challenges that the communities were facing as a result of mine operations and involuntary resettlement, as well as maximising the benefits and opportunities to the project stakeholders. Based on the identified needs and expectation of a variety of community groups, the company has initiated community development projects which, gradually, evolved into strong partnerships with the local government, contractors, social institutions and NGOs. In monetary terms, 2018 Masan contributed 5.545 billion Vietnamese Dong (227.422 €) to projects covering areas such as farming and animal husbandry, vocational training and microfinancing, taking its total investment to VND 37.666 billion (1,5 billion €) since 2011 (Wadlow, 2019).

Nevertheless, problems related to environment and health remain as the ecosystem of the mining area is contaminated. An analysis for six trace elements (arsenic (As), Cd,Cr, Cu, Pb and Zn) in the collected soil samples showed that all the soil samples were contaminated by Cd and As at levels ,up to 16 and 23 times higher, respectively, compared with the Vietnamese soil quality standard for agriculture so that this area is rated as extremely polluted by Cd, severely to moderately–heavily polluted by As and slightly to moderately polluted by other elements such as Cr, Cu, Pb and Zn. The source of these contaminations is attributed to the

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Nui Phao mining activities. The study area had high potential ecological risk, and the carcinogenic risk value was higher than the acceptable value. This means that the local resident health is strongly affected by Nui Phao mining activities both directly and indirectly via food consumption, when rice plant grown in the paddy field is the dominant crop in the study area (Nguyen et al, 2020).

RESEARCH AND DEVELOPMENT TRENDS

- HiTech AlkCarb[6]: New geomodels to explore deeper for High-Technology critical raw materials in Alkaline rocks and Carbonatites (2016 – 2020, EU)

Heavy and light rare earth elements, niobium, fluorspar, and phosphate, as well as hafnium (Hf), tantalum (Ta), scandium (Sc) and zirconium (Zr) are commonly found in association with alkaline rocks and in particular in carbonatites. In Central and Southern Europe, the presence of abundant alkaline volcanic rocks indicates the likelihood that deposits exist within about a km of the surface. The project will make a step-change in exploration models for alkaline and carbonatite provinces, using mineralogy, petrology, and geochemistry, and state-of-the-art interpretation of high resolution geophysics and downhole measurement tools, to make robust predictions about mineral prospectivity at depth. The results will be incorporated into new geomodels on multiple scales.

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