SCRREEN2

This project has received funding from the European

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

TALC

AUTHOR(S):

TABLE DES MATIÈRES

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TALC

OVERVIEW

Talc ($Mg_3Si_4O_{10}(OH)_2$) is a hydrous magnesium silicate mineral (BGS, 2016) and belongs to the group of phyllosilicates. The elementary sheet is composed of a layer of magnesium-oxygen/hydroxyl octahedra, sandwiched between two layers of siliconoxygen tetrahedra. Talc is the world's softest mineral (Mohs' hardness of 1). Talc is formed under hydrothermal conditions and it frequently arises in association with chlorite, magnesite and serpentine. Talc is generated in two different alteration processes, either hydrothermal alteration of ultramafic rocks or siliceous hydrothermal alteration of Mg-limestone or dolomite. This results in two types of deposit, with talc being is a so-called secondary mineral or alteration mineral.

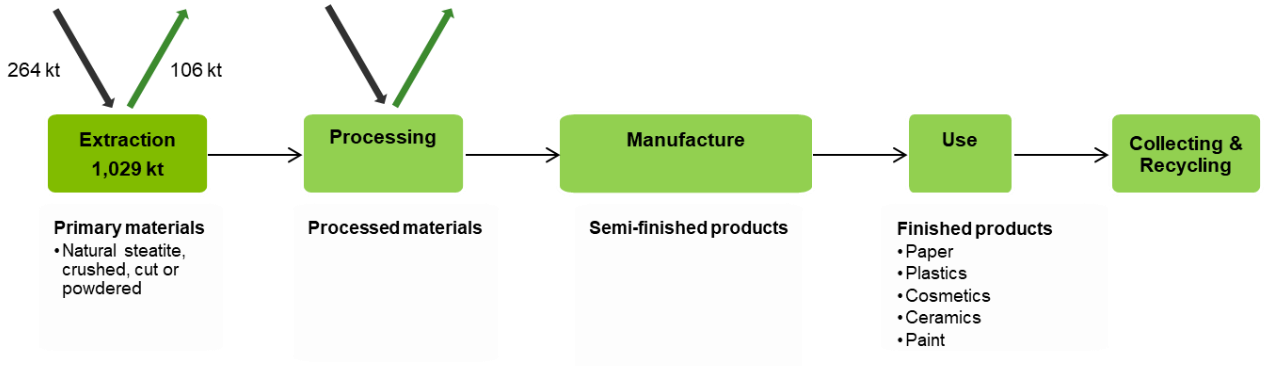

Figure 1. Simplified value chain for talc in the EU[1]

Table 1. Talc supply and demand in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
7,193,575	India 22% China 20% Brazil 10% US 8% South Korea 6% Finland 5% France 5% Japan 4% Canada 3% Turkey 3%	1,116,290	15.5%	Pakistan 42% India 17% Australia 16% China 13% US 4% Egypt 4%	7%

Prices: Talc prices in 2020 have increased by 2.4 times compared with the 2009 prices. Furthermore, talc applications in rubber, ceramic tile and sanitaryware, paint, and cosmetics industries are the main drivers of prices changes in the past decade (USGS, 2022b).

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

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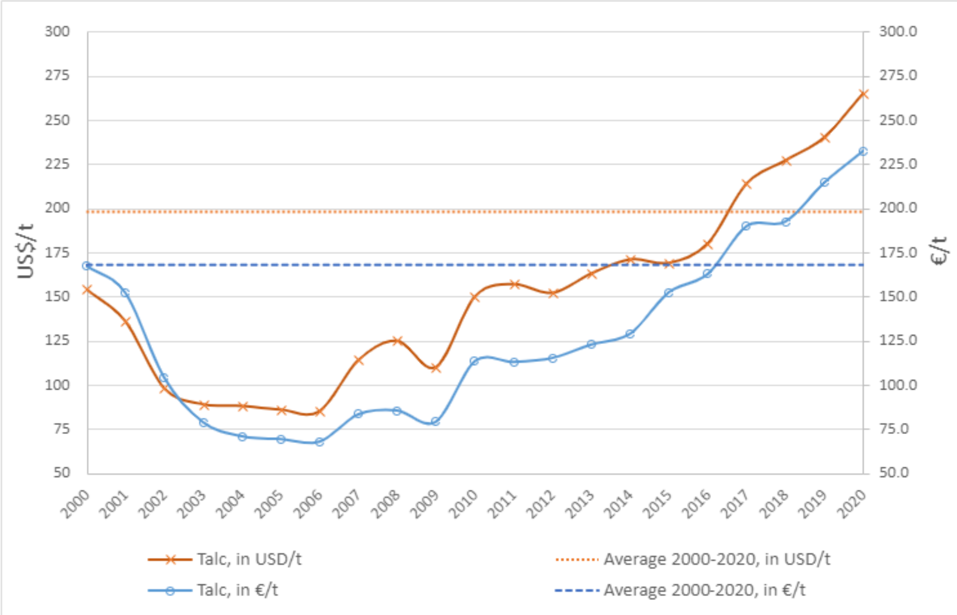

Figure 2. Annual average price of talc between 2000 and 2020 (USGS, 2021)[2].

Primary supply: The world annual production of talc between 2016 and 2020 was 7.8 Mt on average. China is the largest producer with 26% of the total output in the mentioned period. India is the second with 21% of the total, followed by Brazil and the United States (WMD, 2022). The average annual talc production in EU in the period 2016-2020 was 1.04 million tonnes. France, Finland, Italy and Austria are the major producers. The exported annual amount at the same period was 0.975 million tonnes.

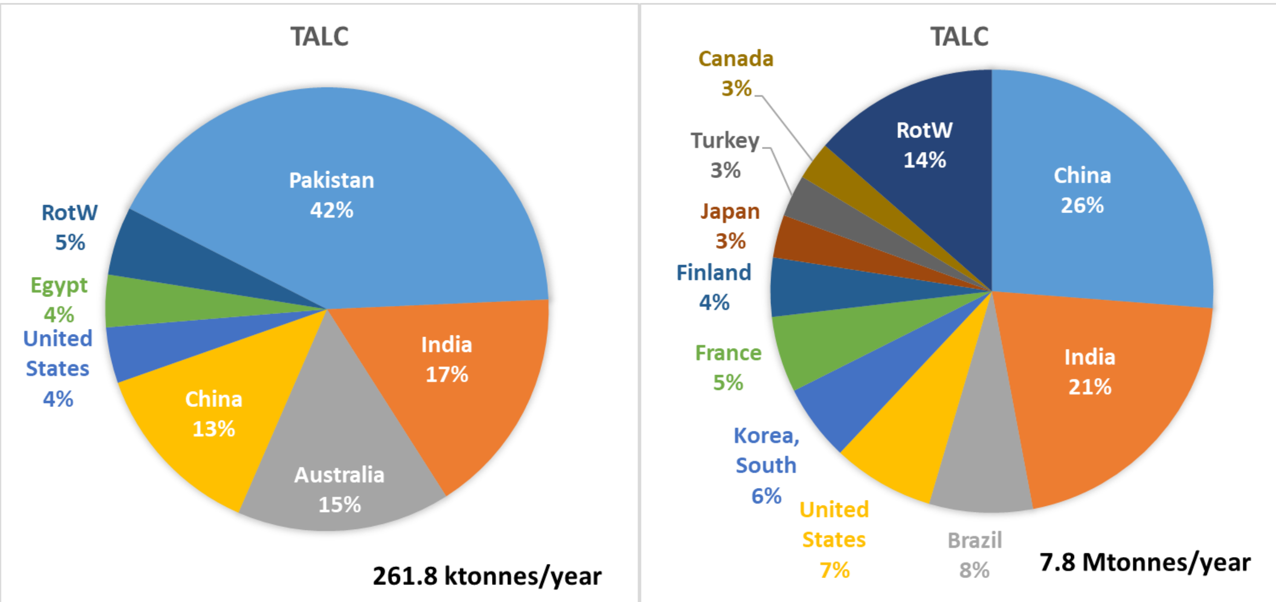

Figure 3. EU sourcing of talc and global mine production

[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: The recycling rate of talc is high in several industrial sectors (IMA-Europe, 2018, Eurotalc, 2019) but it depends on the recycling of the talc containing product, and not from direct talc recycling. As the calculation of supply risk is concerned, end of life recycling input rate (EoL-RIR) for talc was estimated at 16% (SCRREEN workshops, 2019).

Uses: In Europe, the largest applications of talc involve the sectors of car industry as polymers (34%), paper (21%), paints and coatings (18%), construction as building materials (7%) and other uses including fertilizers, rubber, cosmetics, pharmaceuticals, etc.

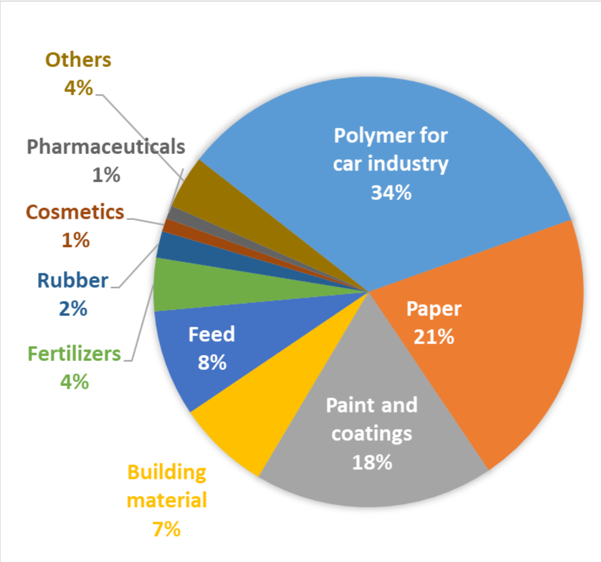

Figure 4: EU uses of talc

Substitution: According to the various end-uses of talc, different properties of the minerals are required for the given application. Depending on these properties there are potential substitutes for talc.

Table 2. Uses and possible substitutes

Use	Percentage*	Substitutes	Sub share	Cost	Performance
Polymer for car industry	34%	Calcium carbonate	10%	Similar or lower costs	Reduced
Paper	21%	Calcium carbonate	10%	Similar or lower costs	Reduced
		Kaolin	10%	Similar or lower costs	Reduced
Paint and coatings	18%	Calcium carbonate	20%	Similar or lower costs	Reduced

*Estimated end use shares of talc based on IMA (2019), validated by SCRREEN experts (2022). Subshares and substitutes validated by SCRREEN experts (2022); USGS (2022)

Other issues: (Drechsel et al. 2018) provide an overview on the historical evolution of the regulatory standards for occupational and consumer exposures to industrial talc. The scientific association of European talc producers look into sustainable practices in talc mining and processing, mainly focusing on emission control, waste management, water/energy conservation and hazardous products. (EUROTALC 2023).

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GLOBAL MARKET

Table 3. Talc (extraction) supply and demand in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
7,193,575	India 22% China 20% Brazil 10% US 8% South Korea 6% Finland 5% France 5% Japan 4% Canada 3% Turkey 3%	1,116,290	15.5%	Pakistan 42% India 17% Australia 16% China 13% US 4% Egypt 4%	7%

India (22%), China (20%) and Brazil (10%) are the main producers for talc production. Main players include Golcha Minerals, Imerys, IMI Fabi, Mondo Minerals, and Nippon Talc.

Between 2020 and 2021, the use of talc in rubber production increased significantly due to the demand of rubber stoppers in the medical industry for the large quantities of COVID-19 vaccines (USGS, 2022a).

The talc demand for other industries - such as ceramic tile, sanitary ware, paint, and paper manufacturing – decreased due to technological changes, and regulations to reduce volatile emissions (USGS, 2022a). Overall, the supply and demand changes on a longer term are expected to be rather stable and balanced compared to each other.

EU TRADE

For this assessment, talc is evaluated at extraction stage.

Table 4. Relevant Eurostat CN trade codes for talc

Mining	
CN trade code	**title**
25261000	Natural steatite and talk (not crushed, not powdered)
25262000	Natural steatite and talk (crushed or powdered)

Figure 5 shows the import and export trend of natural steatite and talk (not crushed, not powdered). The EU exports is much lower than the EU import. The EU import has been fluctuating since 2000, with the minimum import reached in 2009 during the economic crisis and in 2020 during the COVID-19 pandemic. Instead, the EU export seemed to maintain the same level during this period. Figure 6 illustrates the share of import in EU for Natural steatite and talk (not crushed, not powdered) from various countries. The main suppliers to EU in

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the past two decades (2000-2021) have varied between Australia, China, Pakistan, India, and Egypt. Export tax measure for CN 252610 from Egypt has been identified in OECD industrial raw materials Inventory. The measure was introduced in 2016 and it was extended in 2021 (see OECD, 2022).

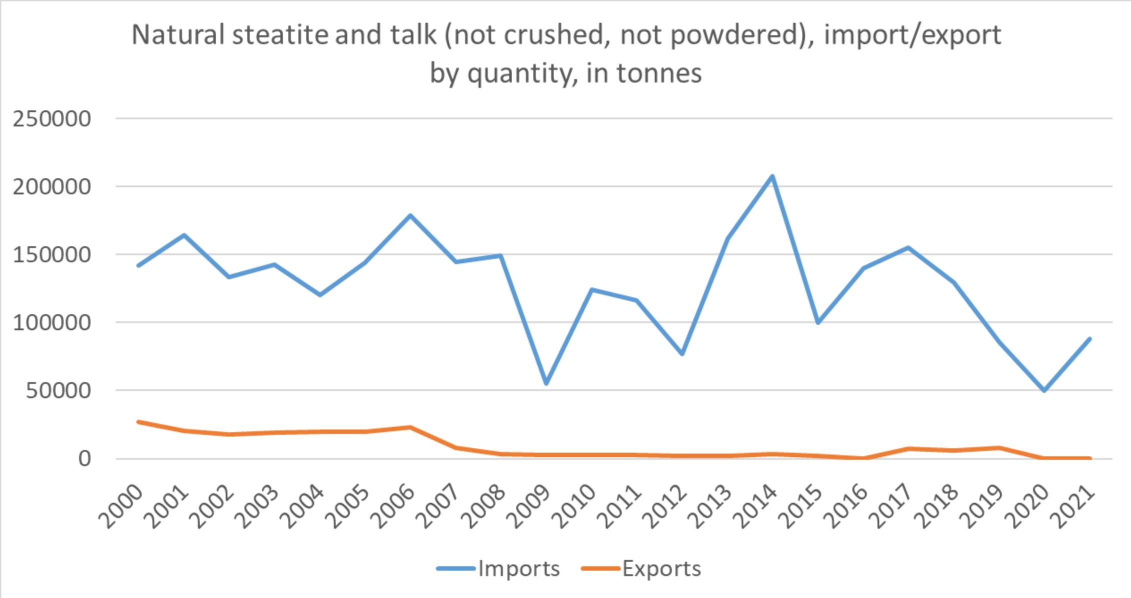

Figure 5. EU trade flows of natural steatite and talk (not crushed, not powdered) (CN 25261000) from 2000 to 2021 (Eurostat, 2022)

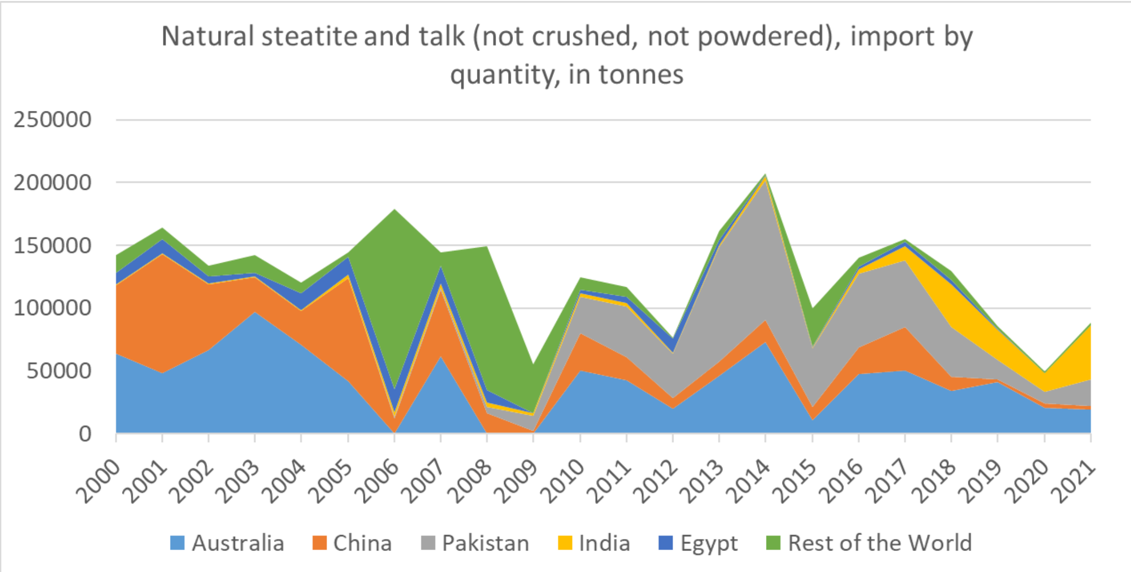

Figure 6. EU imports of natural steatite and talk (not crushed, not powdered) (CN 25261000) by country from 2000 to 2021 (Eurostat, 2022)

Figure 7 shows the import and export trend of 252620 natural steatite and talk (crushed or powdered). Since 2006, the EU export of this product has been increasing, and exceeded the import starting from 2012. The EU import in 2021 was 180,328 tonnes while the export was 193,127 tonnes. Figure 8 illustrates the share of import in EU for 252620 Natural steatite and talk (crushed or powdered) from various countries. China was

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the major supplier to the EU from 2002-2009. From 2009 until recently in 2021, Pakistan has been the major supplier to the EU. Other suppliers to the EU are Egypt, India, and the United States.

Egypt introduced an export tax for Natural steatite and talk (crushed or powdered) on 50 Micron and below and only on super fine powder Talc at a value of 300 Egyptian pound /tonnes in 2017 and it remained valid in 2002 (see OECD, 2022).

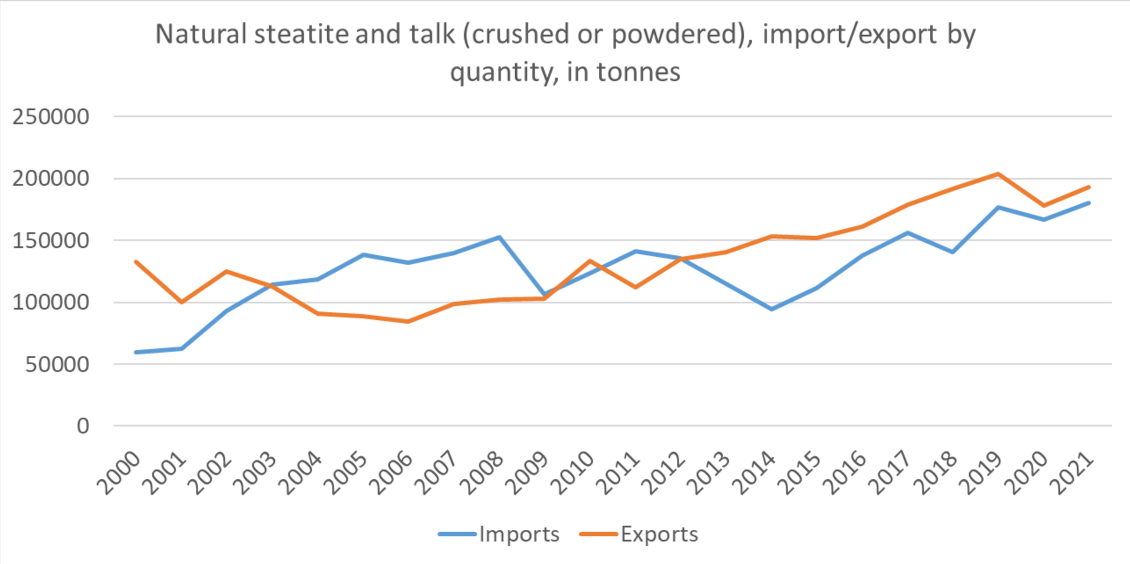

Figure 7. EU Trade flows of natural steatite and talk (crushed or powdered) (25262000) from 2000 to 2021 (Eurostat, 2022)

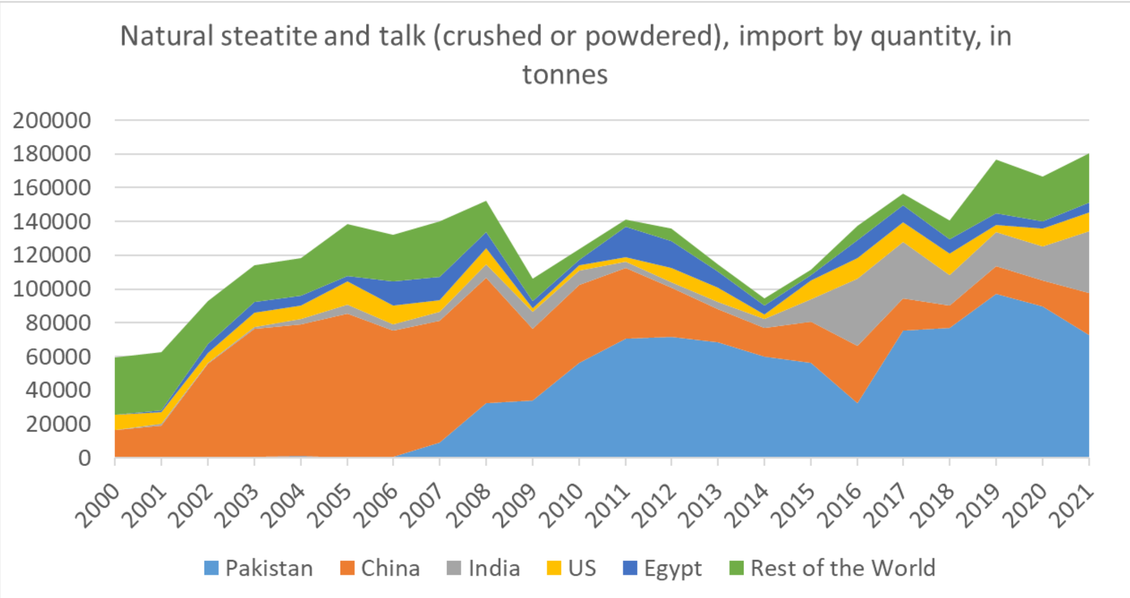

Figure 8. EU imports of natural steatite and talk (crushed or powdered) (25262000) by country from 2000 to 2021 (Eurostat, 2022)

PRICE AND PRICE VOLATILITY

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Talc prices in 2020 have increased by 2.4 times compared with the 2009 prices. Furthermore, talc applications in rubber, ceramic tile and sanitaryware, paint, and cosmetics industries are the main drivers of prices changes in the past decade (USGS, 2022b).

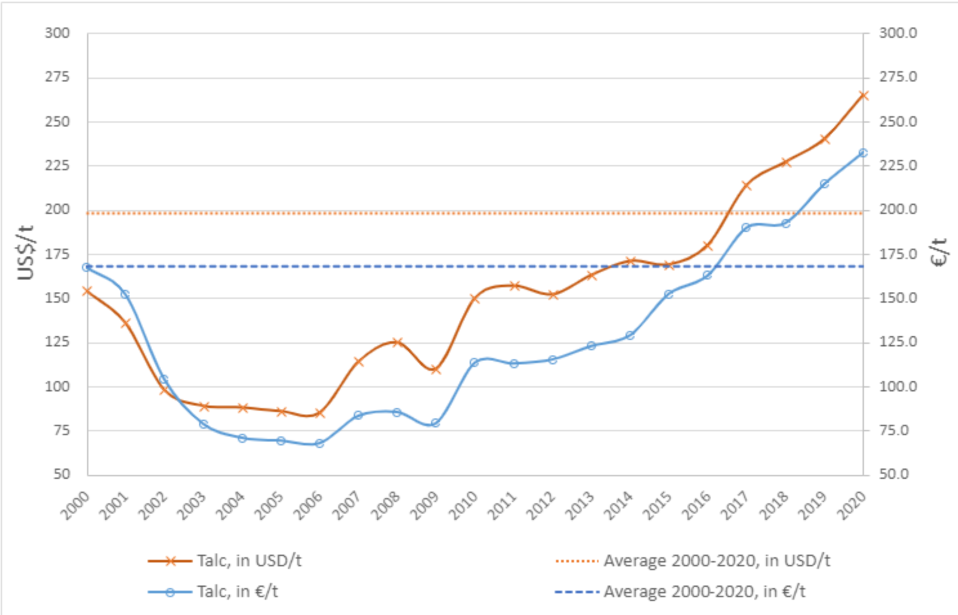

Figure 9. Annual average price of talc between 2000 and 2020, in US$/t and €/t[3]. Dash lines indicate the average price for 2000-2020 (USGS, 2022b)

DEMAND

GLOBAL AND EU DEMAND AND CONSUMPTION

Talc EU consumption is assessed at extraction stage. Talc extraction stage EU consumption is presented by HS code CN 25261000 - Natural steatite, whether roughly trimmed or merely cut (by sawing or otherwise) into blocks or slabs of a square or rectangular shape, and talc, uncrushed or unpowdered and CN 25262000 - Natural steatite and talc, crushed or powdered. Import and export data is extracted from Eurostat Comext (2022). Production data is extracted from BGS (2021).

[3] Values in €/t are converted from original data in US$/t 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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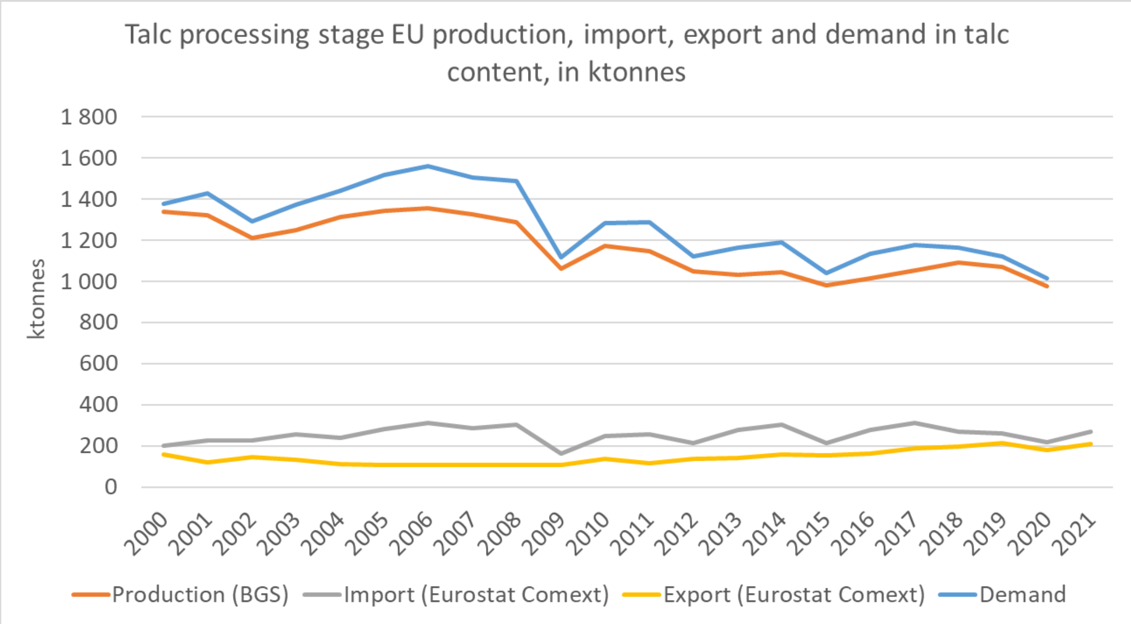

Figure 10. Talc (CN 25261000, CN 25262000) extraction stage apparent EU consumption. Production data is available from BGS (2021). Consumption is calculated in talc content (EU production+import-export).

Average import reliance of at extraction stage is 7 % for 2016-2020.

EU USES AND END-USES

In Europe, the largest applications of talc involve the sectors of car industry as polymers (34%), paper (21%), paints and coatings (18%), construction as building materials (7%) and other uses including fertilizers, rubber, cosmetics, pharmaceuticals, etc.

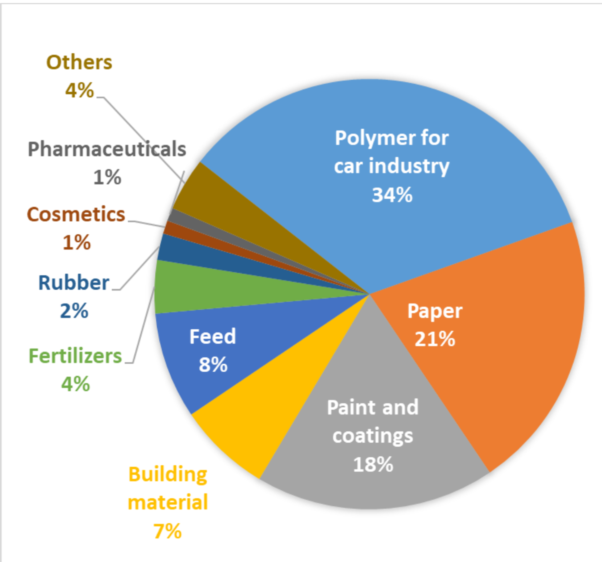

Figure 11. EU end uses of talc (IMA-Europe, 2018), average 2012-2016. Unchanged from 2020 factsheets, validated by SCRREEN experts, 2022

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The calculation of economic importance is based on the use of the NACE 2-digit codes and the value added at factor cost for the identified sectors. The value-added data correspond to 2019 figures.

Table 5. Talc applications (IMA-Europe, 2018), 2-digit NACE sectors associated 4-digit NACE sectors and value added per sector (Eurostat 2021).

Applications	2-digit NACE sector	Value added of sector (millions €)	4-digit NACE sector
Polymer for car industry	C22 - Manufacture of rubber and plastic products	94,767	C22.21 -Manufacture of plastic plates, sheets, tubes and profiles
Paper	C17 - Manufacture of paper and paper products	47,452	C17.23 -Manufacture of paper stationery
Paint and Coatings	C20 - Manufacture of chemicals and chemical products	117,150*	C20.30 - Manufacture of paints, varnishes and similar coatings, printing ink and mastics
Building material	C23 - Manufacture of other non-metallic mineral products	72,396	C23.32 - Manufacture of bricks, tiles and construction products, in baked clay
Feed	C10 - Manufacture of food products	251,015**	C10.89 - Manufacture of other food products n.e.c.
Fertilizers	C20 - Manufacture of chemicals and chemical products	117,150*	C20.15 - Manufacture of fertilisers and nitrogen compounds
Rubber	C22 - Manufacture of rubber and plastic products	94,767	C22.21 -Manufacture of plastic plates, sheets, tubes and profiles
Cosmetics	C21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations	94,336*	C21.20 -Manufacture of pharmaceutical preparations
Pharmaceuticals	C21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations	94,336*	C21.10 - Manufacture of basic pharmaceutical products
Others	C21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations	94,336*	C21.10 - Manufacture of basic pharmaceutical products

* Data to 2014 only
** includes C11 & C12

Talc has numerous applications in a variety sectors, with a dependency on purity and whiteness (IMA-Europe, 2018; IMA-Europe, 2019).

It can be used, for example, to produce:

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- polymers for the car industry.
- uncoated and coated rotogravure papers, where it enhances printability and reduces surface friction, improving productivity at the paper mill and print house. Talc also improves 'mattness' and reduces ink scuff in offset papers.
- interior and exterior decorative paints, offering a whole range of benefits to coatings and acting as extender to improve hiding power and titanium dioxide efficiency. Talc's lamellar platelets makes paint easier to apply and improves cracking resistance and sagging (and enhances matting).
- building materials; talc as a phyllosilicate imparts a wide range of functions to floor and wall tiles, sanitary-ware, tableware, refractories and technical ceramics. In traditional building ceramics (tiles and sanitaryware) it is used as a flux, enabling firing temperatures and cycles to be reduced.
- additives in food or feed, cosmetics, pharmaceuticals or fertilizers.

SUBSTITUTION

According to the various end-uses of talc, different properties of the minerals are required for the given application. Depending on these properties there are potential substitutes for talc.

Table 6. Uses and possible substitutes

Use	Percentage*	Substitutes	Sub share	Cost	Performance
Polymer for car industry	34%	Calcium carbonate	10%	Similar or lower costs	Reduced
Paper	21%	Calcium carbonate	10%	Similar or lower costs	Reduced
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*Estimated end use shares of talc based on IMA (2019), validated by SCRREEN experts (2022). Subshares and substitutes validated by SCRREEN experts (2022); USGS (2022)

For **paint and coatings**, talc could be substituted by chlorite. It is possible to use mica and kaolin as substitutes, but their properties are different, and the requirements of the use should not be too demanding.

Talc can be replaced by kaolin in **paper coating** in gravure printing application. Talc is normally more expensive than kaolin and this condition has spurred the search for substitute materials. Talc cannot be replaced by calcium carbonate or kaolin when used as "pitch and stickies" preventing agent.

Bentonite, chlorite, feldspar, kaolin, and pyrophyllite can be used **in ceramics**; compared to kaolin talc is more expensive but it performs better.

Mica can replace talc in **plastics** when high stiffness is required, although there will be a drastic reduction of impact resistance. Mica is a niche material when compared to talc and its cost is generally higher (IMA, 2019).

Wollastonite can replace talc in **some specific products** (from all kinds of applications).

For **agrochemical applications**, talc can be substituted by fuller's earth, kaolin, diatomite, perlite, gypsum, and sepiolite.

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SUPPLY

EU SUPPLY CHAIN

As with many industrial minerals, the industry (mineral products, construction materials, chemical productions, paper manufacturing) in the EU takes the raw materials inputs directly from extraction and wholesale businesses.

The average annual talc production in EU in the period 2016-2020 was 1.04 million tonnes. France, Finland, Italy and Austria are the major producers. The exported annual amount at the same period was 0.975 million tonnes. About 51 thousand tonnes are annually imported in EU in natural steatite form. The recycling rate of talc in EU is estimated at 16%.

The only country imposing trade restrictions related to talc is China. It applied an export quota between 500 kt and 700 kt between 2010 and 2014, an export tax of 10% and a licensing requirement (OECD, 2016).

SUPPLY FROM PRIMARY MATERIALS

GEOLOGY, RESOURCES AND RESERVES OF TALC

GEOLOGICAL OCCURRENCE

Talc ($Mg_3Si_4O_{10}(OH)_2$) is a hydrous magnesium silicate mineral (BGS, 2016) and belongs to the group of phyllosilicates. The elementary sheet is composed of a layer of magnesium-oxygen/hydroxyl octahedra, sandwiched between two layers of siliconoxygen tetrahedra (IMA, 2019). The main or basal surfaces of this elementary sheet do not contain hydroxyl groups or active ions, which explains talc's hydrophobicity and inertness. In its massive and impure form the mineral is also known as steatite and soapstone. The mineral has a greasy feel because of its very low hardness. On the Mohs scale of hardness talc is ranked at "1", thus it is the softest mineral on this scale, and its density varies from 2.7 to 2.8 g/cm^3 (Tufar, 2000). Talc is practically insoluble in water and in weak acids and alkalis; talc's melting point is 1,500°C.

Although all talc ores are soft, platy, water repellent and chemically inert, talc ores are almost never similar (IMA, 2019). Talc originates from environments of weak metamorphism. It is formed under hydrothermal conditions and it frequently arises in association with chlorite, magnesite and serpentine. Talc is generated in two different alteration processes, either hydrothermal alteration of ultramafic rocks or siliceous hydrothermal alteration of Mg-limestone or dolomite. This results in two types of deposit, with talc being is a so-called secondary mineral or alteration mineral.

Talc ores also differ according to the type and proportion of associated minerals present. They can be divided into two main types of deposits: talc-chlorite and talc-carbonate. Talc-chlorite ore bodies consist mainly of talc (sometimes 100%) and chlorite, which is hydrated magnesium and aluminium silicate. Chlorite is lamellar, soft and organophilic like talc. It is however slightly less water repellent than talc. Talc-carbonate ore bodies are mainly composed of talc carbonate and traces of chlorite. Carbonate is typically magnesite (magnesium

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carbonate) or dolomite (magnesium and calcium carbonate). Talc-carbonate ores are processed to remove associated minerals and to produce pure talc concentrate. (IMA-Europe, 2019).

GLOBAL RESOURCES AND RESERVES:

Talc deposits are widespread and mined worldwide. USGS (2021) provides some rough data about global[4] and EU[5] reserves of talc. It is not likely that more accurate reserve estimations will be available in the coming years.

Table 7: Global reserves of talc in year 2021 (USGS, 2022).

Country	Talc reserves (ktonnes)
United States	140.000
India	110.000
Japan	100.000
China	82.000
Korea, Republic of	81.000
Brazil	45.000
Finland	Large
France	Large
Other countries	Large
World total (rounded)	Large

WORLD AND EU MINE PRODUCTION

The global annual production of talc between 2016 and 2020 was annually 7.8 Mt on average. China is the largest talc producer with 26% of the total output in the mentioned period. India is the second producer worldwide with a 21% of the total, followed by Brazil and the United States (WMD, 2022). The large share of other countries extracting talc indicates that operations are widespread and locations significantly depend on transport costs.

[4] There is no single source of comprehensive evaluations for resources and reserves that apply the same criteria to deposits of talc in different geographic areas of the EU or globally. The USGS collects information about the quantity and quality of mineral resources but does not directly measure reserves, and companies or governments do not directly report reserves to the USGS. Individual companies may publish regular mineral resource and reserve reports, but reporting is done using a variety of systems of reporting depending on the location of their operation, their corporate identity and stock market requirements. Translations between national reporting codes are possible by application of the CRIRSCO template (www.crirsco.com), which is also consistent with the United Nations Framework Classification (UNFC) system. However, reserve and resource data are changing continuously as exploration and mining proceed and are thus influenced by market conditions and should be followed continuously.

[5] For Europe, there is no complete and harmonised dataset that presents total EU resource and reserve estimates for talc. The Minerals4EU (2019) project is the only EU-level repository of some mineral resource and reserve data for talc, but this information does not provide a complete picture for Europe. It includes estimates based on a variety of reporting codes used by different countries, and different types of non-comparable datasets (e.g. historic estimates, inferred reserves figures only, etc.). In addition, translations of Minerals4EU (2019) data by application of the CRIRSCO template is not always possible, meaning that not all resource and reserve data for talc at the national/regional level is consistent with the United Nations Framework Classification (UNFC) system. Many documented resources in Europe are based on historic estimates and are of little current economic interest. Data for these may not always be presentable in accordance with the UNFC system.

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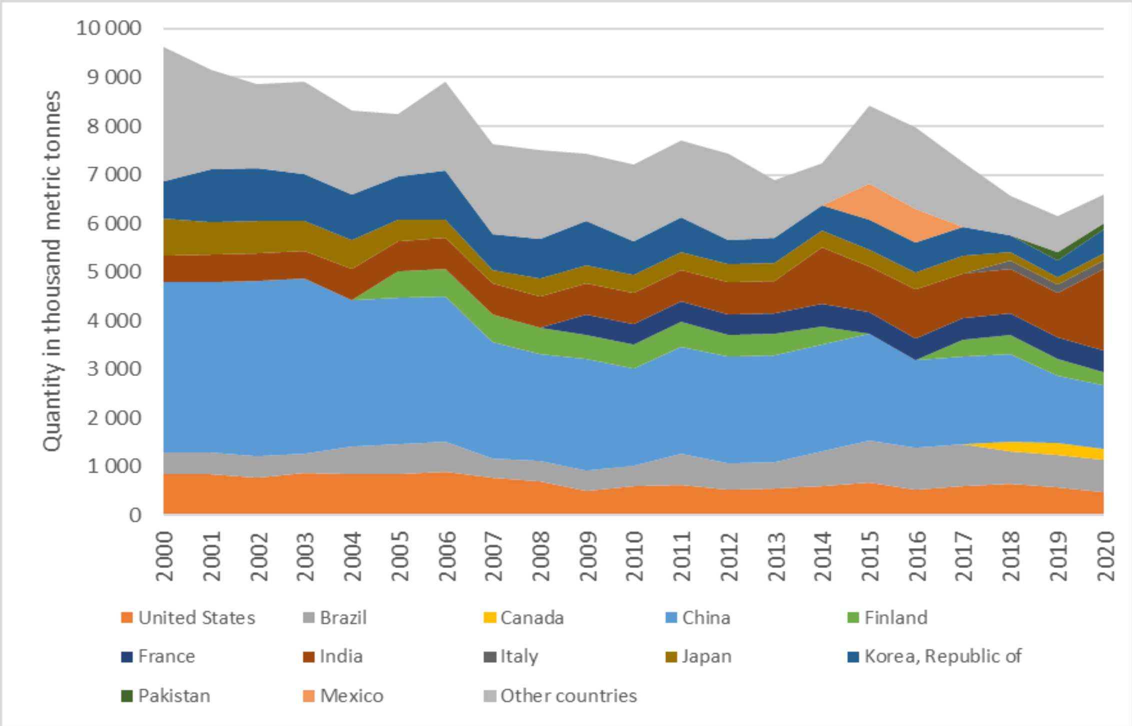

Figure 12. Global mine production of talc from 2000 to 2020 (USGS, 2022)

According to WMD (2022), the global production of talc is similar than the USGS results, as can be observed in the following figure.

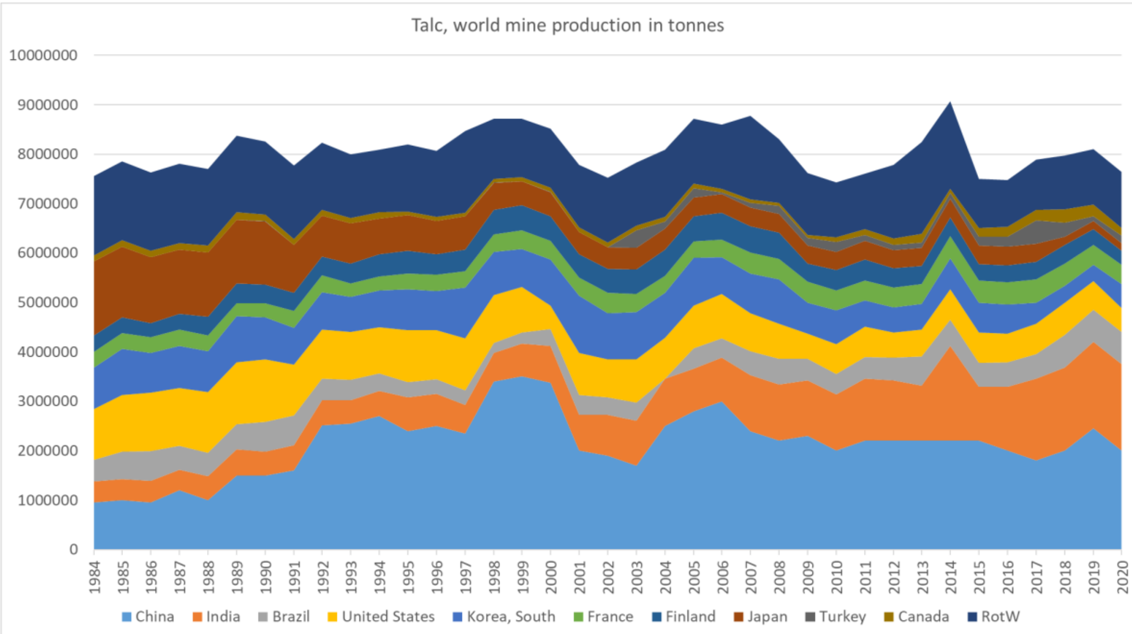

Figure 13: Global mine production of talc from 1984 to 2020 (Federal Ministry of Agriculture, Regions and Tourism of Austria (Ed.): WMD (since 1984))

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The talc production from EU countries amounts to 1,041 kt in average during the period 2016-2020, which represent 14.5% of the global production. Within the EU, Talc is mainly produced in France (37% of EU production), Finland (26% of EU production), Italy (15% of EU production) and Austria (11% of EU production).

PROCESSING

Extracted talc minerals are first subjected to a comminution process that involves crushing, grinding and sieving. After that, talc beneficiation usually uses hand picking, photoelectric picking, electrostatic dressing, flotation, dry or wet magnetic separation, dry grinding air classification, micro powder technology and talc layered, selection process. At present, the mature beneficiation research and test technology contain photoelectric pick and bleaching. In addition to the grinding work, the beneficiation plant also can use flotation process to select low grade ores and can do comprehensive recovery of beneficial associated minerals (Zenith, 2016).

SUPPLY FROM SECONDARY MATERIALS/RECYCLING

The recycling rate of talc is high in several industrial sectors (IMA-Europe, 2018, Eurotalc, 2019). More specifically:

As talc used in polymers for car manufacturing is concerned, recycled plastics are mainly used for under-the-bonnet automotive parts, arch liners, cable harness plugs, water and sewage pipes, furniture feet, chair arm rests and electric motor housings. Thus, to calculate the talc recycling rate in this application the average recycling rate of end-of-life vehicles in the EU, which is 88%, can be used.

Paper fibres are recycled 3.6 times on average in the EU, significantly outperforming the world average of 2.4 times. The recycling rate in Europe increased to 72.5% in 2016.

Interior and exterior paints, which represent 50-60% of the total amount of paint consumed, are recycled the most, principally in aggregates and other construction materials. Therefore, the figures of the recycling of construction and demolition waste can be reasonably used and, considering the large disparities in recycling rates in EU countries, an average recycling rate of 50% can be taken for construction and demolition waste. Also 50% can be used as recycling rate for talc used as building material.

By taking into account that other uses for talc are diverse, it is difficult to establish recycling figures. For instance, talc is used for its functional properties as an additive in food or feed, cosmetics, pharmaceuticals or fertilizers. It is therefore entirely consumed with the relevant products and ultimately returned to nature.

As the calculation of supply risk is concerned, end of life recycling input rate (EoL-RIR) for talc was estimated at 16% (SCRREEN workshops, 2019).

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OTHER CONSIDERATIONS

NORMATIVE REQUIREMENTS

(Drechsel et al. 2018) provide an overview on the historical evolution of the regulatory standards for occupational and consumer exposures to industrial talc. The scientific association of European talc producers look into sustainable practices in talc mining and processing, mainly focusing on emission control, waste management, water/energy conservation and hazardous products. (EUROTALC 2023).

RESEARCH AND DEVELOPMENT TRENDS

RESEARCH AND DEVELOPMENT TRENDS FOR LOW-CARBON AND GREEN TECHNOLOGIES

- Organotalcs for solar energy

Organic-inorganic layered materials, such as organotalcs, are a promising alternative as gelling agent for liquid electrolytes in dye-sensitized solar cells. Talcs could provide an abundant, low cost and environmentally friendly option for solidifying the electrolyte. Talc (Mg3Si4O10(OH)$_2$), functionalized with a polyamidoamine dendron and polyiodides intercalated, is a gelator reaching the same or even better performance and stability than comparable liquid devices (Santana Andrade, Jr., et al 2017). Several works report the use of charged clays containing intercalated cations to gel electrolytes for dye sensitized solar cells. To eliminate possible interferences from these cations, talc $Mg_3Si_4O_{10}(OH)_2$ is applied as gelling agent. Once this clay is functionalized by 1−3 generation dendron polyamidoaminopyridines (PAMPy), the dendrons interact with TiO_2 surface producing a barrier effect, decreasing electrons and holes recombination and, as a consequence, improving solar cell performance (Santana Andrade, Jr., et al. 2017).

- Talc as alternative material for hydrogen storage (HS) alloys

Carbon is frequently used as an anti-sticking agent that prevents agglomerating, bonding and mutual welding of ball-milled particles of hydrogen storage alloys. It is commonly supposed that the carbon does not take part significantly in HS above the room temperature. Hydrogen sorption in three carbon allotropes and in magnesium silicate monohydrate (talc) was studied in temperature interval from 423 to 623 K. HS capacity from about 0.4 wt.% H_2 (talc) to about 1.1 wt.% H_2 (carbon black) was observed at a hydrogen pressure of 25 bar. Also, talc showed anti-sticking effect similar to that of carbon (Cermak et al., 2018).

- Talc for increasing the power of photon absorption

Among the phenolic compounds, the chlorophenols can deteriorate water quality and threaten human health and survival of other organisms. TiO_2 has superior photocatalytic performance due to its strong oxidizing ability, nontoxicity, and long-term stability of photochemistry. Talc can intensify the power of photon absorption and capture-recombination carriers due to its strong adsorption ability, which may thus improve

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the photocatalysis of TiO_2. So novel nanocomposites have been prepared by intercalating TiO_2 nanoparticles into talc. The prepared talc/TiO_2 nanocomposite was an efficient, stable, and recyclable material for wastewater treatment (Ai et al., 2019).

- Talc material for novel efficient and cost-effective heterogeneous catalysts for the production of biodiesel

Nickel-based catalysts with different loadings supported on talc have been successfully synthesised for dry reforming of methane (DRM). All catalysts showed promising catalytic DRM performance and 10 % NiO/Talc was found to be the most effective catalyst with 98 % CH_4 and 80 % CO_2 conversion respectively. 10 % NiO/Talc excellent catalyst stability is very promising for gas processing industries (Shamsuddin et al., 2021). A novel efficient and cost-effective heterogeneous catalyst for the production of biodiesel from transesterification of sunflower oil was prepared through the impregnation of K_2CO_3 upon the Talc material. The optimum loading of the K_2CO_3 species upon the talc support was determined to be 40 wt.%. Furthermore, the developed catalyst was recoverable and reusable for five reaction cycles of its catalytic activity (Salmasi et al., 2020). Microwave-enhanced degradation is an effective method to remove organic contaminants from aqueous solutions. In particular, a novel iron sulphide/talc (FeS_x/talc) composite was prepared for a microwave irradiation process for the treatment of 2,4,6-trichlorophenol (TCP). The maximum chemical oxygen demand (COD) removal was more than 90.1 % when the concentration of FeS_x/talc composite is 1 g/L and the irradiation time of microwave radiation was 5 min, significantly higher than that treated by FeS_x particles or talc. With the advantages of low cost, high physico-chemical stability, and high reusability, this novel FeS_x/talc composite could be a potential treating material for rapidly remove organic pollutants from wastewater (Ai et al., 2021). Currently, 1,3-butadiene (butadiene henceforth) is predominantly produced from naphtha steam crackers used for the production of ethylene. Butadiene has also been synthesized by the conversion of ethanol. A germanium talc catalyst, which selectively produces 1,3-butadiene in the conversion of ethanol, has been developed. Its maximum selectivity was determined as 71 %, 40 % conversion of ethanol at 673 K (Akiyama et al., 2018).

OTHER RESEARCH AND DEVELOPMENT TRENDS

- FUTURE-PRINT[6] project: Tuneable 2D Nanosheet Networks for Printed Electronics (EU, 2016 – 2023)

In the future, even the most mundane objects will contain electronic circuitry allowing them to gather, process, display and transmit information. Realising this vast Internet of Things network will require the ability to produce electronic circuitry extremely cheaply, often on unconventional substrates. This will be achieved through printed electronics, by the assembly of devices from solution (i.e. ink) using methods adapted from printing technology. However, while printed electronics has been advancing rapidly, the development of new, nano-materials-based inks is required for this area to meet its true potential. Recent developments in liquid exfoliation of 2D nanosheets give the ideal family of materials to revolutionise electronic ink production. Liquid exfoliation can transform layered crystals into suspensions of nanosheets in very large quantities. In this way we can produce liquid-dispersed nanosheets of a wide range of types including conducting (e.g. graphene, MXenes, TiB_2 etc), semiconducting (e.g. MoS_2, WSe_2, GaS, Black phosphorous etc), insulating (e.g. BN, talc) or electrochemically active (e.g. MoO3, $Ni(OH)_2$, MnO_2 etc) ones. These nanosheets can be deposited from liquid

[6] CORDIS EU research results, 10.3030/694101

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to form porous, defined electronic networks with huge applications potentials, but a large amount of work must be done to translate them into working printed devices. Methods will therefore be developed in the project to transform large volume suspensions of exfoliated nanosheets into bespoke 2D inks with properties engineered for a range of specific printed device applications. We will learn to use this 2D ink to print patterned or large area 2D nanosheet networks with controlled structure, allowing us to tune the electrical properties of the network during printing. We will combine networks of different nanosheet types into complex heterostructures. This will allow us to print all device components (electrodes, active layers, dielectrics, energy storage layers) from one contiguous, multi-component network. In this way we will produce 2D network transistors, solar cells, displays and energy storage systems. FUTURE-PRINT will revolutionise electronic inks and will offer a new path forward for printed electronics.

- An investigation into the tensile properties of recycled high-density polyethylene (rHDPE) blended with talc filler (Malyuta et al. 2023)

High-density polyethylene (HDPE) is a well-established thermoplastic; however, with concerns about the fate of plastics at end-of-life, there is a growing interest in strategies to utilize recycled HDPE (rHDPE) in place of virgin HDPE (vHDPE). This study investigated the tensile properties of rHDPE/talc blends (0, 20, 28, and 38 wt% talc) and adequate talc dispersion was found in the blends using scanning electron microscopy imaging. Increases in tensile strength (up to 20.4 %), elastic nominal stiffness (up to 93.5%), and a decrease in nominal yield strain (up to 50 %) were observed for rHDPE with increasing talc content. The trends observed indicate that rHDPE could be a viable alternative/supplement to vHDPE for use in large volume structural applications. If talc filler particle dispersion can be well monitored, the rHDPE/talc blends have significant potential to be used and hence reduce the amount of virgin material needed; however, additional properties should be further explored.

- Water-based lubricant containing protic ionic liquids and talc lubricant particles: Wear and corrosion analysis (de Castro et al. 2023)

Water-based lubricants have been used in different industrial applications in recent years. However, studies evaluating the tribological and electrochemical effects of lubricants with Protic Ionic Liquid (PIL) and talc particles (TC) as additives on SAE 1010 and SAE 1045 steels are still scarce in literature, which is the objective of this work. Samples extracted from steel sheets were investigated in the normalized (SAE 1010) and quenched-tempered (SAE 1045) conditions. Wear tests in a ball-on-plate type tribometer and corrosion tests using potentiodynamic polarization curves were performed in the presence of different lubricant solutions (PIL 3 % + DI water, commercial lubricant 3 % + DI water, with and without talc particle additions 0.05 and 0.1 wt%). Analyses of viscosity, pH, wettability, and particle size distribution were conducted on the lubricant and talc samples. Wear and corrosion surfaces were analysed by SEM/EDS, and Raman techniques. The results showed that the tribofilm formed from the interaction between PIL lubricants and steel substrates decreased the wear due to the increase of lubricity of these lubricants. When the PIL and the commercial lubricants are compared, PIL additives presented higher performance, despite the talc addition. The influence of talc on the corrosion of steel is associated with the differential aeration effect, mitigated by adding the PIL.

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