SCRREEN2

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

TANTALUM

AUTHOR(S):

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TANTALUM

OVERVIEW

Tantalum (chemical symbol Ta) is a silvery-grey hard, transition metal. It has a high density (16.6 g/cm^3) and the fourth highest melting point (3,020°C). It is highly resistant to corrosion and has a great permittivity. Tantalum's estimated abundance in the upper continental crust is 0.9 ppm (Rudnick, 2003), which is quite rare. It is not found as a free metal in nature but occurs notably in the minerals microlite and tantalite-columbite. Most tantalum is produced as a co-product as it occurs in complex mineral form, often associated in ore bodies with niobium, tin or lithium.

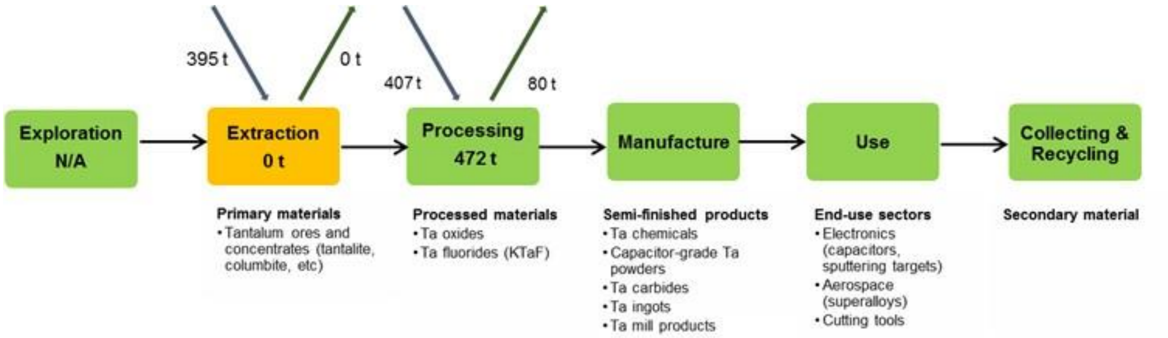

Figure 1. Simplified value chain for tantalum in the EU[1]

Table 1. Tantalum supply and demand (extraction) in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
1867 tonnes	Congo, D.R. 35% Rwanda 17% Brazil 16% Nigeria 11%				100%

Prices: Tantalum is not traded on any metals exchange, and there are no terminal or futures markets where buyers and sellers can fix an official price. References for prices are obtained through averages of past deals between private parties, generally available through paid subscription, such as Asian Metal, and Metal Pages

Primary supply: According to the WMD global mine production of tantalum between 2010 and 2020 ranged from 799 t (2010) and 2,260 t (2017). Main producing countries of tantalum are Democratic Republic of Congo, Rwanda, Brazil, China, Nigeria and Mozambique. Until 2008 Australia used to be the most important supplier of tantalum, but its production decreased significantly and now accounts only minor share in global production.

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

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Secondary supply: According to the Matos et al. (2021) EU processing sector in 2016 used 164 t of imported secondary raw material and 2 t of imported waste for the tantalum production. Secondary tantalum from domestic scrap (old scrap, new scrap from fabrication of semi-finished products as well as new scrap from manufacturing of finished products, referring to "functional recycling") is also an important input (193 t tantalum content –new 108t of new scrap and 95 t of old scrap) to produce tantalum processed materials

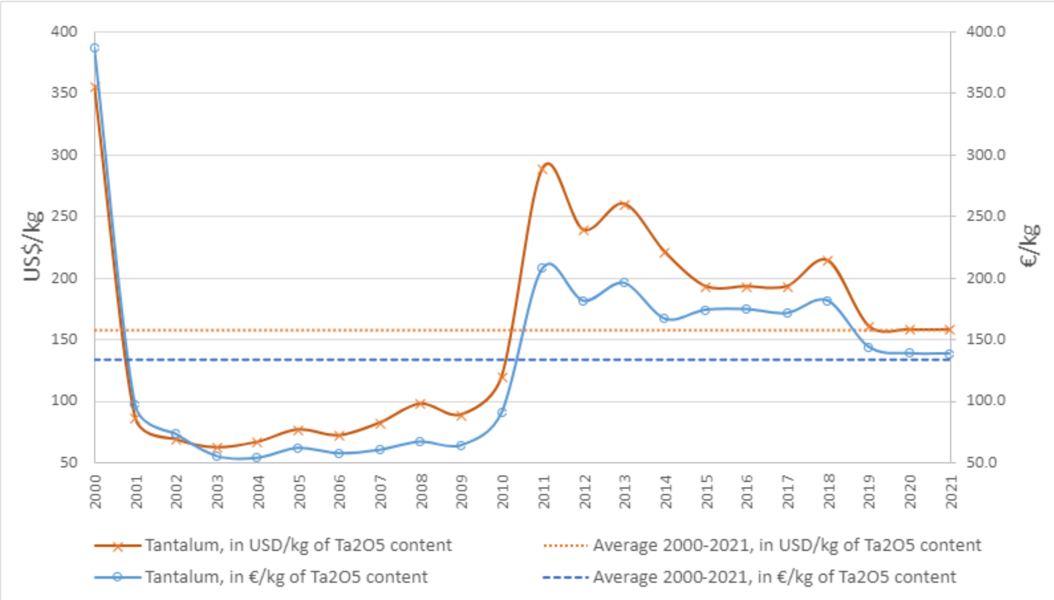

Figure 2. Annual average price of tantalum, in kg of Ta2O5 content, between 2000 and 2020 (USGS, 2021)[2].

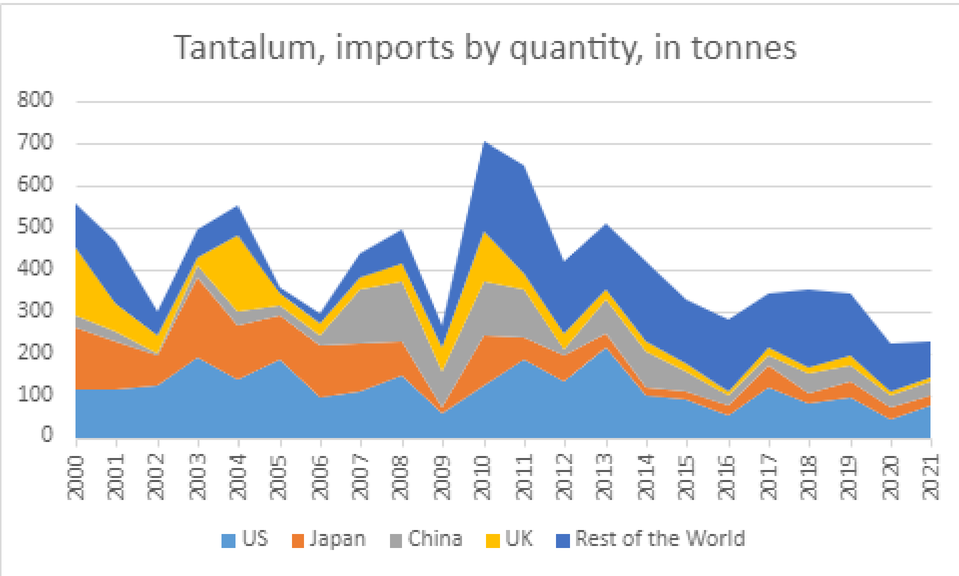

Figure 3. EU sourcing of tantalum articles, including waste and scraps.

[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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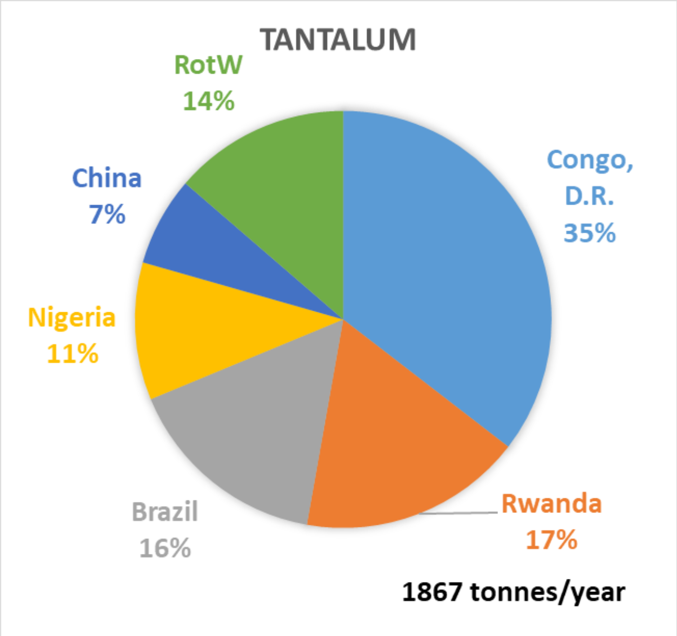

Figure 4. Global mine production, Ta2O5 content (average 2016-2020)

Uses: The manufacture of capacitors is the largest single use of tantalum worldwide. Superalloys are an important use of tantalum in the EU, due to the prominence of the aerospace sector. Roskill estimates that the EU could consume half of tantalum used globally in superalloys (Roskill, 2016).

Substitution: Substitutes of tantalum for different applications remain the same as in the years 2010-2020. No major change has been identified (SCRREEN Expert workshop 2021; SCRREEN Validation workshop, 2022).

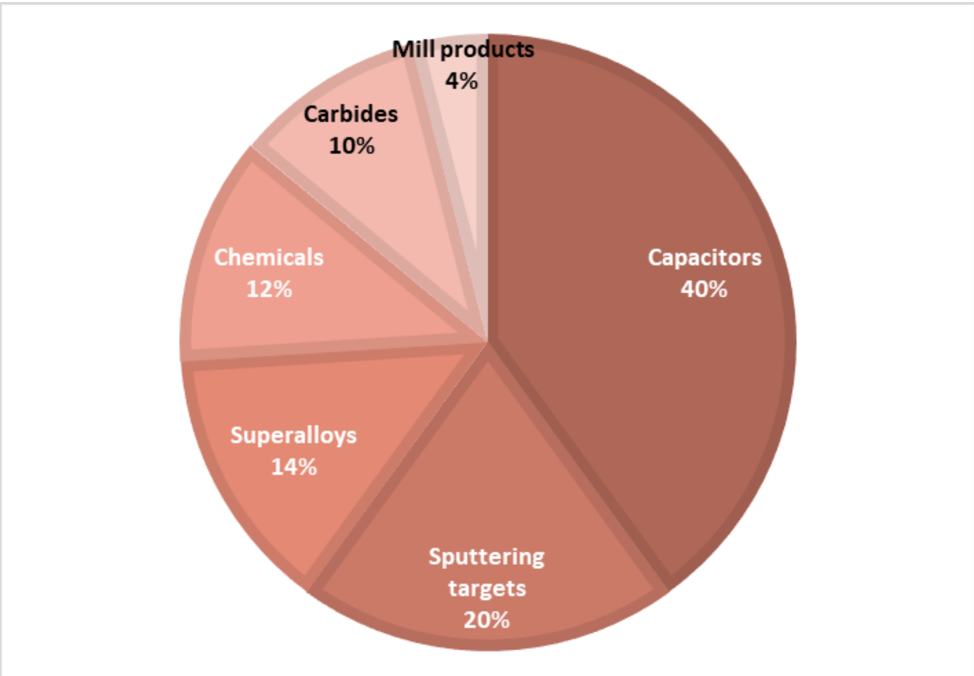

Figure 5: EU uses of tantalum

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Table 2. Uses and possible substitutes

Use	Share*	Substitutes	Sub share	Cost	Performance
Carbides	9%	Tungsten	25%	Similar or lower costs	Similar
Carbides	9%	Niobium	25%	Similar or lower costs	Similar
Carbides	9%	Titanium	25%	Similar or lower costs	Similar
Carbides	9%	Molybdenum	25%	Similar or lower costs	Similar
Mill Products	12%	Titanium	50%	Similar or lower costs	Similar
Mill Products	12%	Niobium	50%	Similar or lower costs	Similar
Superalloys	24%	Vanadium	14%	Similar or lower costs	Reduced
Superalloys	24%	Hafnium	14%	Slightly higher costs (up to 2 times)	Reduced
Superalloys	24%	Iridium	14%	Very high costs (more than 2 times)	Reduced
Superalloys	24%	Molybdenum	14%	Similar or lower costs	Reduced
Superalloys	24%	Niobium	14%	Similar or lower costs	Reduced
Superalloys	24%	Rhenium	14%	Similar or lower costs	Reduced
Superalloys	24%	Tungsten	14%	Similar or lower costs	Reduced
Chemicals	8%	Platinum	33%	Very high costs (more than 2 times)	Reduced
Chemicals	8%	Zirconium	33%	Similar or lower costs	Reduced
Chemicals	8%	Titanium	33%	Similar or lower costs	Reduced

* Shares of finished-products containing tantalum used in the EU27)

Other issues: Tantalum mining and trade is related to armed conflicts and severe human rights violations and is therefore considered a conflict mineral in legislation (c.f. section "Standards and normative Requirements related to use and processing of the material"). In addition to the conflict minerals issue, 20 % to 25 % of mined tantalum is produced by artisanal and small-scale mining (ASM).

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MARKET ANALYSIS, TRADE AND PRICES

GLOBAL MARKET

Table 3. Tantalum supply and demand in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
1867 tonnes	Congo, D.R. 35% Rwanda 17% Brazil 16% Nigeria 11%				100%

An estimated of 2,750 t of tantalum ores and concentrates were consumed in the global market in the form of engineered powder, wire, rods, ingots and sheets in 2021 alone (TTI, 2021). The electronics industry is the leading application for tantalum where it is used in the manufacture of capacitors and sputtering targets (H2020 Tarantula, 2020).

The main primary source of tantalum is minerals such as tantalite-columbite, microlite, wodginite, struverite, and cassiterite hosted in igneous rocks (e.g. pegmatites, granites, carbonatites). Most tantalum is produced as a co-product as it occurs in complex mineral form, often associated in ore bodies with niobium, tin or lithium (European Commission, Joint Research Centre, 2021). Tantalum can also be extracted as a by-product of tin smelter waste (tin slags), converted to a synthetic concentrate of a tantalum content suitable for standard chemical processing. Such source can be responsible for 20% to 50% of total Ta production, depending on available supply and prices (European Commission, Joint Research Centre, 2021). The third source of tantalum is recovery from secondary sources, such as new scrap from manufacturing of Ta powders and ingots as well as manufacturing of Ta containing products (and, end-of-life scrap, although the quantity is not significant) (European Commission, Joint Research Centre, 2021).

At processing stage, in the tantalum industry distinction is often made between "primary processors" and "secondary processors (TIC, 2021). Primary processors are equivalent of smelters, with the capability to process tantalum mineral concentrates or slags, also secondary concentrates, synthetic concentrates, and scrap. Secondary processors handle tantalum intermediates and process them into final products. The inputs and outputs from these processors are different. The first one can produce anything from K-salt to high purity oxides or capacitor-grade tantalum metal powder while the secondary processor may buy salt, metallurgical grade tantalum metal or tantalum ingot and process them into oxides, capacitor grade powder, or metal products (TIC, 2021). Almost half of the companies identified as consumers of Tantalum ore and concentrates are in China (The International Trade Administration, 2020).

EU TRADE

For the purpose of this assessment, Tantalum is evaluated at processing stage. There is no data on tantalum trade as such. Figure 6displays the EU trade in Tantalum (in tonnes of Tantalum articles including waste and scrap (CN 8103) between 2000 and 2021. The imports of Tantalum (CN 8103) varied from 559 t in 2000 to 226 t in 2021, while the exports ranged between 651 t and 426 t per year for the same period.

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Table 4. Relevant Eurostat CN Trade codes for Tantalum

Mining		Processing/refining	
CN trade code	**title**	**CN trade code**	**title**
26159000	Niobium, Tantalum & Vanadium Ores & Concentrates	**81030000**	Tantalum articles including waste and scrap

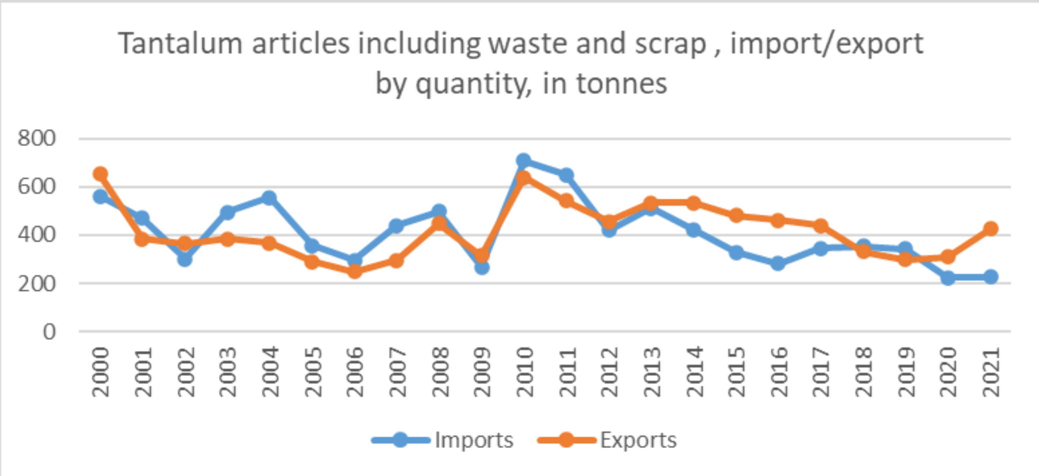

Figure 6. EU trade flows of Tantalum articles including waste and scrap (CN 81030000) from 2000 to 2021 (Eurostat, 2021)

Figure 7 presents the imports of Tantalum by country for the period 2000-2021. The major EU supplier of Tantalum was United States, which corresponds to 29% of EU's Tantalum imports in the period. Japan, China, and the UK followed with 17%, 13%, 11% of total EU imports of tantalum, respectively.

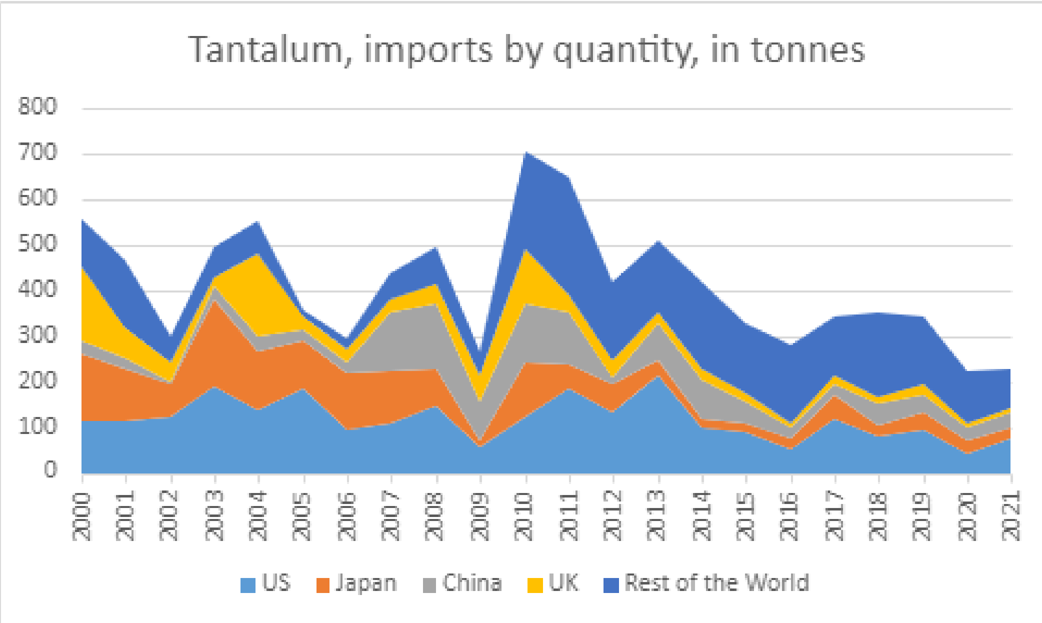

Figure 7. EU imports of Tantalum articles including waste and scrap (CN 81030000) by country between 2000 and 2021 (Eurostat, 2022).

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PRICE AND PRICE VOLATILITY

Tantalum is not traded on any metals exchange, and there are no terminal or futures markets where buyers and sellers can fix an official price. References for prices are obtained through averages of past deals between private parties, generally available through paid subscription, such as Asian Metal, and Metal Pages (Eynard et al., 2020).

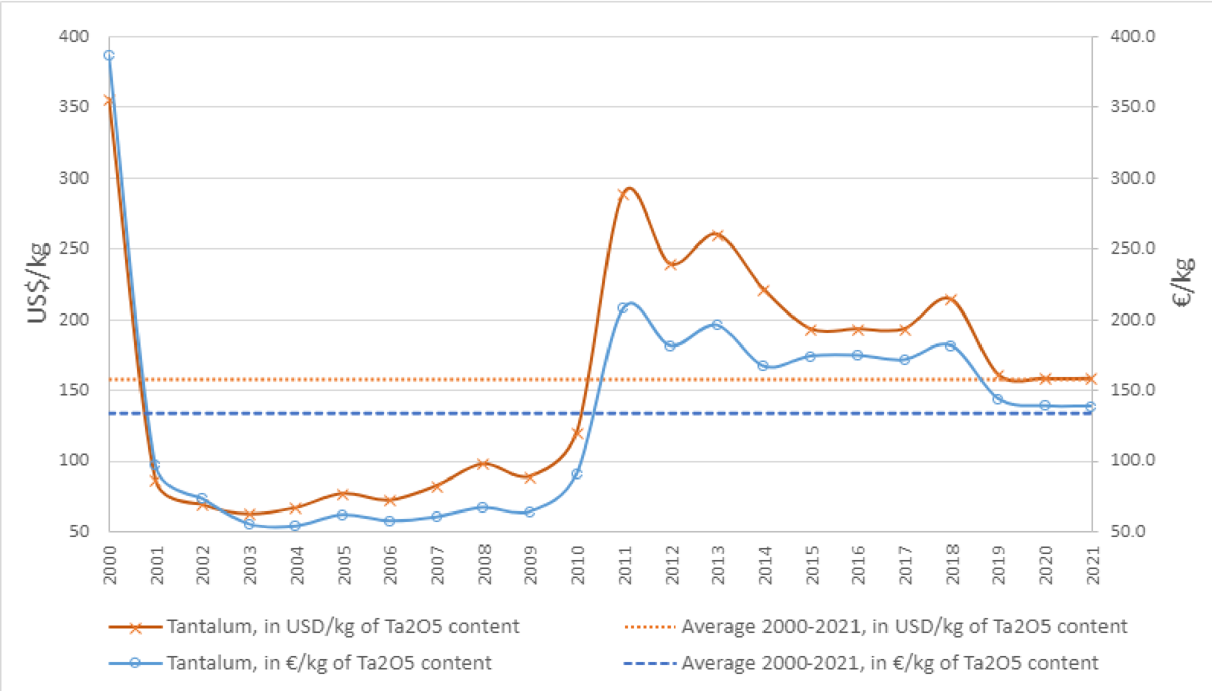

Figure 8. Annual average price of tantalum, in kg of Ta_2O_5 content, between 2000 and 2021, in US$/kg and €/kg 3. (USGS, 2022)

OUTLOOK FOR SUPPLY AND DEMAND

During the COVID-19 pandemic, the demand in electronics was in slow acceleration due to chip production supply bottleneck. The demand in electronics, thus tantalum, however, can still be expected to increase. Currently, the total supply of tantalum from African countries accounted for almost 70%. Most mines are almost exclusively from artisanal and small-scale operations, known to be high-grade and easy to mine. Tantalum from lithium mines is potential but it is not fully effective. Tantalum is expected to be more available due to the increasing demand of electric vehicles, thus also the demand for lithium for batteries. In the future, the extraction could also come from like Australia and Mozambique where there is extraction activity of Lithium.

[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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DEMAND

GLOBAL AND EU DEMAND AND CONSUMPTION

Apparent consumption figures for tantalum derived from adding EU production and imports and subtracting exports are not reliable because of uncertainties related to the amount of tantalum produced, traded, or integrated in finished goods at every level.

The EU consumption of tantalum concentrates, and tantalum pentoxide was estimated to exceed 500 tonnes per year, stable over the year 2012-2016 (T.I.C., 2019).

EU imports were estimated at 395 tonnes annually, equivalent to 25% of the tantalum available in the global market in 2012-2016 (T.I.C., 2019). France and Germany were known as the main importer of tantalum in the EU (T.I.C., 2019).

The extraction or processing stage EU apparent consumption (production + imports- exports) of tantalum for 2000-2020 cannot be calculated because of the lack of reliable trade data.

In Eurostat Comext (2022) tantalum also covers niobium and vanadium (CN 261590).

According to World Mining Data (2022) there is no EU production of tantalum for 2009-2020.

EU USES AND END-USES

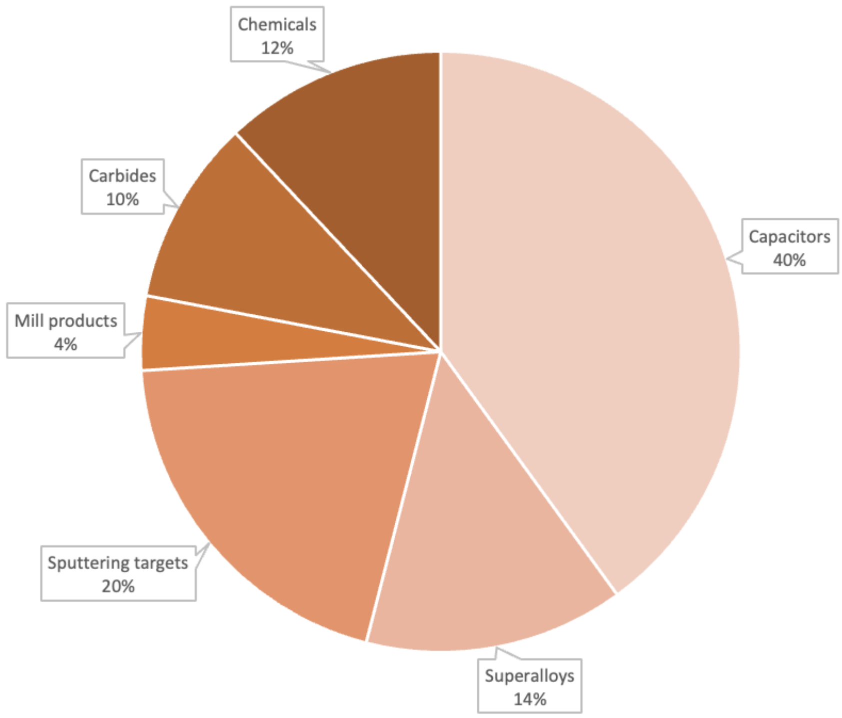

Figure 9. EU27 end uses of tantalum. Average figures for 2012-2016. (SCRREEN 2019, Validated with no update from 2020 factsheets, SCRREEN experts, 2022)

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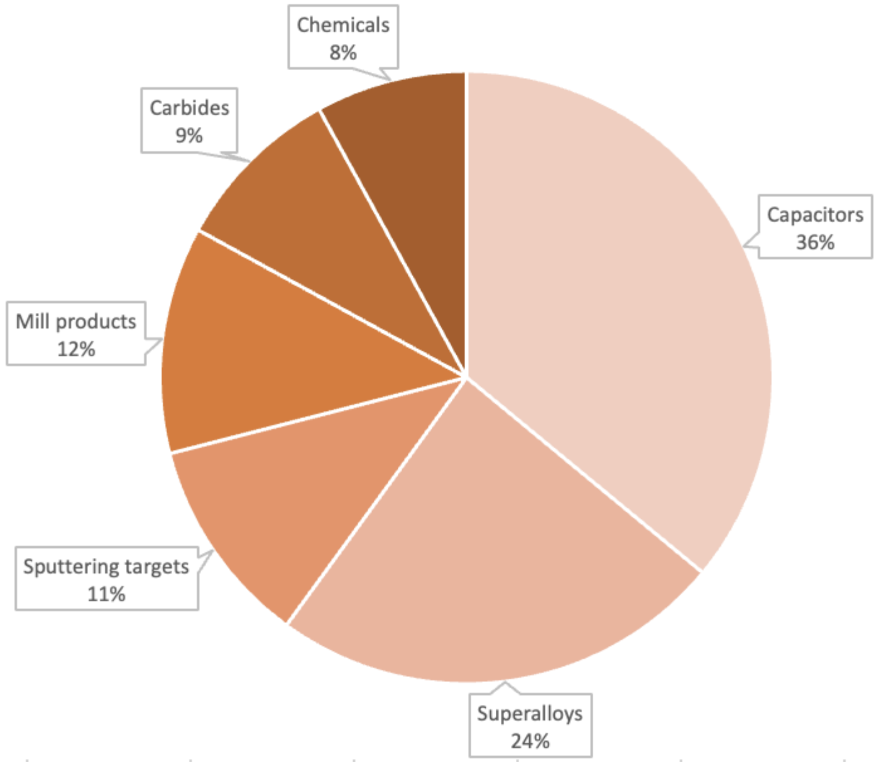

Figure 10 .Shares of finished-products containing tantalum used in the EU (taking into account exports and imports of products), JRC, 2021

Relevant industry sectors are described using the NACE sector codes (Eurostat, 2019c).

Table 5. Tantalum applications, 2-digit and associated 4-digit NACE sectors, and value added per sector (Eurostat, 2019c)

Applications	2-digit NACE sector	Value added of NACE 2 sector (millions €) 2019	4-digit CPA sectors
Capacitors	C26 - Manufacture of computer, electronic and optical products	84,074	C2610- Manufacture of electronic components
Aerospace	C30 – Manufacture of other transport equipment	49,129*	C3030- Manufacture of air and spacecraft and related machinery
Sputtering targets	C26 - Manufacture of computer, electronic and optical products	84,074*	C2610- Manufacture of electronic components
Mill products	C25 - Manufacture of fabricated metal products, except machinery and equipment	186,073	C2593- Manufacture of tools
Carbides	C28 – Manufacture of machinery and equipment n.e.c	200,138*	(C2824-Manufacture of machinery for mining, quarrying and construction)
Chemicals	C20 – Manufacture of chemicals and chemical products	117,150*	C2029-Manufacture of other chemical products n.e.c.

* data to 2014 only

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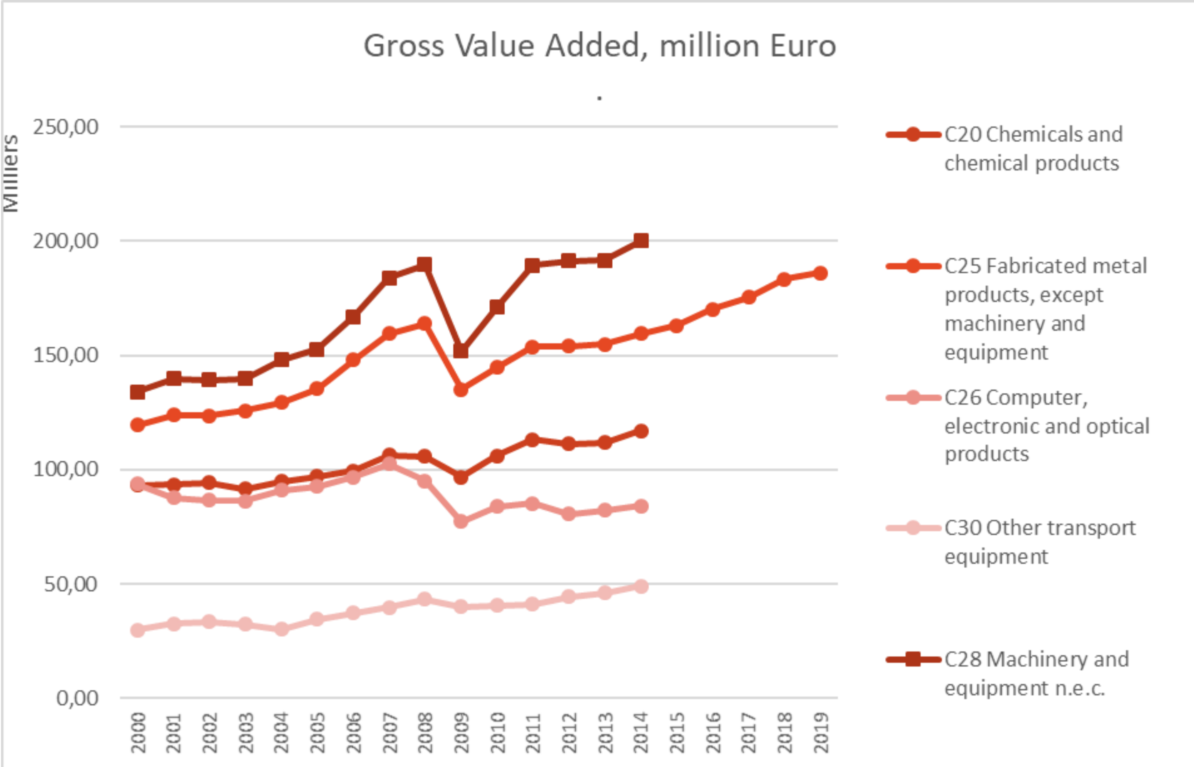

Figure 11. Value added per 2-digit NACE sector over time (Eurostat, 2022))

APPLICATIONS OF TANTALUM IN THE EU

CAPACITORS

The manufacture of capacitors is the largest single use of tantalum worldwide.

All electronic devices contain capacitors, they are used to store an electrical charge for later use, and consist of two conducting surfaces (metal plates) separated by a dielectric insulating material. In the case of tantalum capacitors, the dielectric is a thin film of tantalum pentoxide that forms naturally on the surface of tantalum metal to protect it from corrosion.

The vast majority of capacitors in electronic devices do not contain tantalum; the use of tantalum is favoured when high capacitance, small size and high performance are required.

Such capacitors are now limited to applications where they are irreplaceable.

In the EU, the majority of tantalum use in capacitors comes from imported finished products rather than manufacturing.

In 2016, only one capacitor manufacturer seems to be active, AVX in Czech Republic (European Commission, 2017).

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SUPERALLOYS / AEROSPACE

Superalloys are an important use of tantalum in the EU, due to the prominence of the aerospace sector. Roskill estimates that the EU could consume half of tantalum used globally in superalloys (Roskill, 2016). As aircraft design and performance expectations improve, the alloys involved become more sophisticated and the loading of tantalum in alloys is increasing (together with other specialty metals). Superalloys find applications in the manufacture of jet engines for example, but also for land-based gas turbines.

SPUTTERING TARGETS

Sputtering targets are another major application for tantalum although less important in the EU (only in imported finished products).

Sputtering is a method of applying thin films of metal to a substrate and is used in the manufacture of storage media, inkjet printer heads, electronic circuitry and flat-panel displays, among others. The target is the source of the metal that is deposited.

CHEMICALS

Tantalum chemicals have a very wide range of applications and are intermediates in the manufacture of other products that are often destined for the electronics industry.

MILL PRODUCTS

Tantalum mill products have a very wide range of uses, including chemical processing equipment, ballistics and surgical implants. Tantalum carbides are used in cutting tools.

OTHERS

Tantalum is also used in medical applications (medical device implants, bone and joint replacements), but with a very low share (<1%).

SUBSTITUTION

Substitutes of tantalum for different applications remain the same as in the years 2010-2020. No major change has been identified (SCRREEN Expert workshop 2021; SCRREEN Validation workshop, 2022).

Table 6. Uses and possible substitutes for tantalum

Use	Share*	Substitutes	Sub share	Cost	Performance
Carbides	9%	Tungsten	25%	Similar or lower costs	Similar
Carbides	9%	Niobium	25%	Similar or lower costs	Similar
Carbides	9%	Titanium	25%	Similar or lower costs	Similar
Carbides	9%	Molybdenum	25%	Similar or lower costs	Similar
Mill Products	12%	Titanium	50%	Similar or lower costs	Similar

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Mill Products	12%	Niobium	50%	Similar or lower costs	Similar
Superalloys	24%	Vanadium	14%	Similar or lower costs	Reduced
Superalloys	24%	Hafnium	14%	Slightly higher costs (up to 2 times)	Reduced
Superalloys	24%	Iridium	14%	Very high costs (more than 2 times)	Reduced
Superalloys	24%	Molybdenum	14%	Similar or lower costs	Reduced
Superalloys	24%	Niobium	14%	Similar or lower costs	Reduced
Superalloys	24%	Rhenium	14%	Similar or lower costs	Reduced
Superalloys	24%	Tungsten	14%	Similar or lower costs	Reduced
Chemicals	8%	Platinum	33%	Very high costs (more than 2 times)	Reduced
Chemicals	8%	Zirconium	33%	Similar or lower costs	Reduced
Chemicals	8%	Titanium	33%	Similar or lower costs	Reduced

* Shares of finished-products containing tantalum used in the EU27)

CAPACITORS

Most capacitors in electronic devices do not contain tantalum, mostly because of their high prices.

Niobium can be used to produce capacitors at lower cost, but they are usually larger and have a shorter lifespan ((also considered a critical raw material for the EU since 2011).

Other alternatives are ceramic capacitors (multilayer or monolithic), or standard aluminium capacitors (both are larger in size, have reduced capacitance and are more sensitive to harsh and hot operating conditions).

The superior performance and robustness of tantalum capacitors remains the only reliable choice in applications where long-term reliability, size and/or security matters (e.g. automobile anti-lock brake systems, airbag activation systems, satellites, etc.).

CUTTING TOOLS

Tantalum carbides are used in cutting tools.

Other refractory metals which share similar properties of strength and resistance at high temperatures can be substitutes for carbides (tungsten, niobium, titanium, molybdenum), although prices are often comparable (and again, many of the alternatives are also critical materials).

SUPERALLOYS

In many types of superalloys tantalum is one of several elements added to the base metal (nickel, cobalt or iron) in small, but precise, quantities.

Substituting tantalum for another element would dramatically alter the properties of the superalloy.

Once a particular superalloy has been engineered into an aero engine, or industrial gas turbine, and approved for commercial use, any subsequent change to that superalloy would take many years to become established.

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Tantalum plays a critical role in superalloys and in this application it is a relatively minor cost, making substitution unlikely.

SUPPLY

EU SUPPLY CHAIN

According to the Matos et al. (2021) EU production of the tantalum processed materials (tantalum oxides Ta_2O_5 and fluorides K_2TaF_7) in 2016 amounted to 634 t of tantalum. Input to the EU tantalum refining sector comes entirely from imports of tantalum primary raw materials and from processing of secondary raw materials (Figure 12).

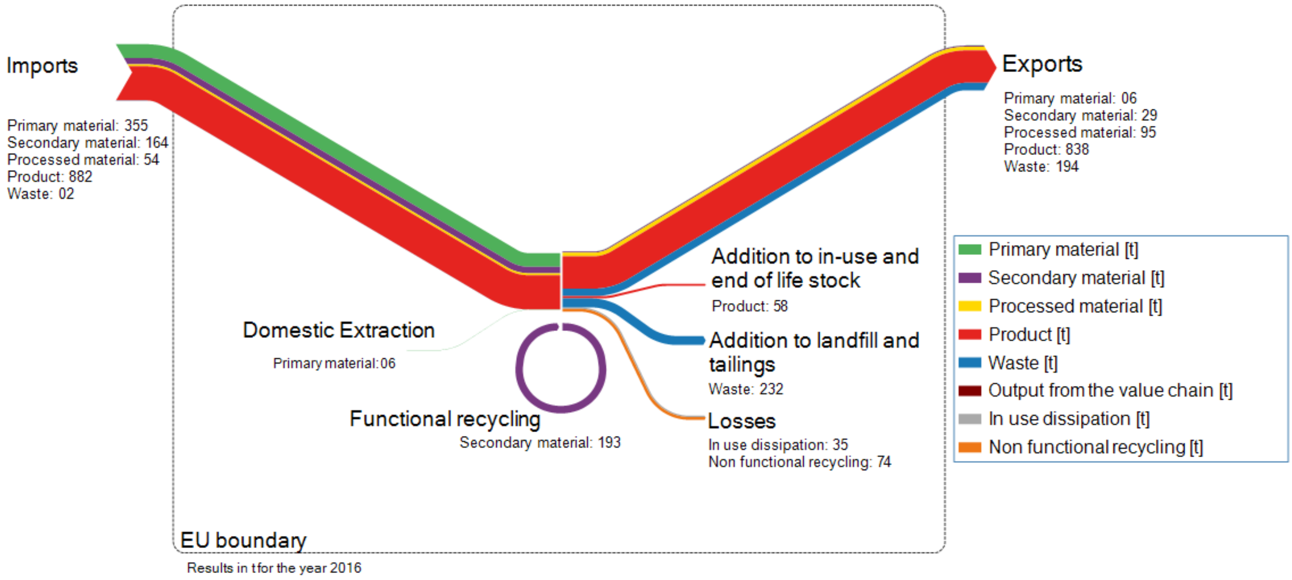

Figure 12. Simplified Sankey diagram for tantalum for the year 2016 in the EU 27. Figure for functional recycling includes both new (108 t tantalum) and old scrap (85 t tantalum) (Matos et al., 2021).

World Mining Data does not report any tantalum production in the EU. However, production of tantalum synthetic concentrate is known to take place by Imerys kaolin mine in Echassières, in France, producing between 4.5 and 6 tonnes of Ta_2O_5 per year but the whole amount is exported to Brazil and India (Bourgeois et al., 2017 and Matos et al., 2021).

In January 2022 tantalite/columbite concentrate production commenced in the Penouta open pit mine in the Galicia (NW Spain). In first 5 months of operation, they produced 29.8 t of tantalite/columbite concentrate with 17-19% of tantalite and 19-21,5 % of columbite (Strategic Minerals Europe Corp, 2022).

Processing of the imported tantalum raw materials is taking place in Germany, Estonia, Austria, Czech Republic, Belgium and France.

The exact data for tantalum import and export are not known since PRODCOM trade code 07.29.19.40 Niobium, tantalum or vanadium ores and concentrates covers three different commodities.

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EU tantalum processing sector relies almost entirely on the import of tantalum primary and secondary raw materials - in 2016 import is estimated on 355 t of tantalum raw materials and 164 t of tantalum secondary raw materials (Matos et al., 2021).

According to the WITS (2022), EU import of the 07.29.19.40 Niobium, tantalum or vanadium ores and concentrates in period 2016-2021 relied mainly on Brazil, DR Congo, India, Kuwait, Mexico, Nigeria, Rwanda, Russia, South Africa, Ukraine and the United States of America. Main import partners for tantalum semi-finished (such as unwrought bars, rods) in from 2016 onwards were China, Hong Kong, Japan, Kazakhstan, Mexico, Republic of Korea, Russia, Thailand, the United States of AmericaTantalum synthetic concentrate produced by Imerys kaolin mine in Echassières, in France is exported to the Brazil and India (Bourgeois et al., 2017).

Table 7. Relevant Eurostat PRODCOM production codes for tantalum

Mining		Processing/refining	
Prodcom code	**title**	**Prodcom code**	**title**
07.29.19.40	Niobium, tantalum, vanadium or zirconium ores and concentrates - Other	20.13.64.51	Carbides of aluminium, of chromium, of molybdenum, of vanadium, of tantalum; of titanium, whether or not chemically defined
		24.45.30.20	Tantalum, unwrought, incl. bars and rods of tantalum obtained simply by sintering; tantalum powder.
		24.45.30.21	Tantalum and articles thereof. Bars and rods, other than those obtained simply by sintering, profiles, wire, plates, sheets, strip and foil
		24.45.30.22	Other articles of tantalum (excluding waste and scrap), n.e.s.
		27.90.52.20	Fixed electrical capacitors, tantalum or aluminium electrolytic (excluding power capacitors)

Functional recycling in the EU which contain domestic EU scrap including old scrap, new scrap from fabrication of the semi-finished products and new scrap from manufacturing of the finished products is an important input of the tantalum for the production of the tantalum processed materials in EU, accounting for 193 t in 2016 (Matos et al., 2021). These contributions resulted in an end-of-life recycling input rate EOL-RIR of 13% and the end-of-life recycling rate EOL-RR of 40%. However, in 2016 approximately 232 t of tantalum was landfilled and lost in slags, while 32 t was lost due to the dissipation and 74 t due to the non-functional recycling (Matos et al., 2021)

SUPPLY FROM PRIMARY MATERIALS

Tantalum is usually co-produced with niobium as they form minerals of similar characteristics which are found in the same types of the ore deposits. It is also commonly associated with tin and lithium ores and can be extracted as by-product. About 50-80 % of tantalum world production comes from primary production, 10-30% from scrap recycling and 10-20% from Sn slags (Matos et al., 2021).

GEOLOGY, RESOURCES AND RESERVES OF TANTALUM

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GEOLOGY

Tantalum does not occur in a free state in nature, but in the form of complex oxides and other minerals. It usually occurs together with niobium in the same type of mineral deposits and in minerals of similar characteristics. Whilst at least nineteen tantalum minerals had been recorded as early as 1982 (Foord, 1982), many of them are only of mineralogical interest. The main ones found in economic quantities are tantalite-columbite, microlite, wodginite and struverite. Tantalum minerals are often associated with cassiterite (the primary source of tin), and such ores are another important source of tantalum.

Tantalite-columbite is an isomorphous series, where tantalum and niobium may substitute with each other. Tantalite is the tantalum-rich end. The common ratios between the two are from 3:1 to 1:3, thus being either tantalo-columbite or columbo-tantalite (which is the most common, also shortened to 'coltan' especially in Central Africa). Microlite is the tantalum-rich end member of the microlite-pyrochlore series. Wodginite is less common but was the primary tantalum mineral found in the original Wodgina deposit in Australia (from which it gained its name) and also at the Tanco mine in Canada. Struverite, a variation of rutile, is a low-grade source of tantalum predominately associated with cassiterite in south-east Asia (Burt, 2016).

All primary tantalum (and niobium) deposits are associated with igneous rocks, and can be grouped into three types, on the basis of the associated igneous rocks:

- Peraluminous pegmatites and granites;
- Alkaline to peralkaline granites and syenites;
- Carbonatite-hosted deposits;
- Placers, paleoplaces and laterites.

Pegmatites have been, and continue to be, the most important source of tantalum mineralization, although only a very small fraction of pegmatites do contain tantalum. The two main periods where tantaliferous pegmatites were intruded are in the Archaean (>2.5 billion years ago) and the Proterozoic (500-1,400 million years ago) (Burt, 2016). Pegmatites are enriched in aluminium compared to the alkali-based minerals (sodium and potassium-rich minerals) (Černý, 1989). Pegmatites are generally relatively small (1-100 million tonnes). They can be 'simple' or 'complex', with several discrete zones within the pegmatite, each zone containing significantly different mineral assemblages. In Central Africa many small pegmatites are found, which have been heavily weathered to the point of kaolinization and have become soft-rock deposits, particularly appropriate for artisanal exploitation.

Alkaline granites are enriched in the alkali-based minerals compared to aluminium. They generally occur in rift or failed rift tectonic settings and are often relatively large deposits (100-1,000 million tonnes), with fine mineralogy (Burt, 2016). These rocks typically contain high contents of zirconium and rare earth elements (REEs) minerals. Significant concentrations of niobium and tantalum also occur, with the primary mineral being pyrochlore. A major example is the Pitinga mine in Brazil which is a Paleoproterozoic albite-rich peralkaline granite, exploited for tin, niobium and tantalum.

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Syenites are another form of alkali feldspathic rock, with dominant nepheline syenite, generally highly complex. The Lovozero deposit in northern Russia is a prime example of an operating mine where tantalum and niobium are important by-products.

Carbonatites are igneous rocks that contain more than 50% carbonate minerals (calcite, dolomite or ankerite). Carbonatites are often associated with alkaline silicate rocks and typically form relatively small intrusions or ring-complexes but in some cases may form larger plutons. Many carbonatites are surrounded by a fenitic aureole produced by metasomatic alteration of the country rocks. Most carbonatites occur in rift settings, although several different types exist, many of which are unmineralized. Some can contain anomalous niobium-tantalum concentrations, along with various rare earth minerals. They are the main sources of niobium extraction. On carbonatites exposed to the warm and humid tropical conditions which cause deep and extensive weathering of the bed rock can be formed also lateritic residual deposits which can contain significant ore grades.

Placers are deposits of heavy minerals transported by a medium such as moving water, or more uncommonly, wind. Their formation is related to localised decrease in the transport capacity (i.e. energy) of the medium, leading to rapid loss of the higher-density components in the transported fractions.

The often hard and dense oxides comprising the major Nb-Ta oxide minerals can easily form such deposits when weathered primary occurrences or deposits are subjected to fluvial erosion and transport. In the case of most better-known Nb-Ta-enriched placers, they occur in relative vicinity of the original host pegmatites, such as in the case of the Mumba tin-tantalum gravel deposit in the Democratic Republic of Congo, where the presence, and hence survival, of softer heavy minerals attest to a quite short distance of fluvial transport (DERA, 2018).

GLOBAL RESOURCES AND RESERVES:

The world reserves of tantalum exceed 140,000 t – Table 8 (USGS, 2022). Additionally 55,000 t of resources are reported for United States but are considered as uneconomic at current tantalum price. Despite the fact that most of the countries does not report tantalum reserves and resources, tantalum reserves are considered sufficient to meet projected demand. World tantalum production is largely dependent on columbite-type minerals, i.e., mainly Fe-Mn-Nb-Ta-oxides from evolved granites and granitic pegmatite-aplite systems as well as on Nb-Ta-enriched cassiterite (Reginiussen et al., 2021).

Table 8. Tantalum reserves by country (USGS, 2022).

Country	Reserves (million tonnes)
Brazil	0.040
Australia	0.094 (among which 0.039 JORC compliant)
Others	N.A.
Total	> 0.140

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Penouta mine in Spain opened at the beginning of 2022 is currently the only active tantalum mine in Europe. Its resources are reported on 7.6 million tonnes measured resources with 85 ppm of tantalum (103 ppm of Ta_2O_5), 68.6 million tonnes of indicated resources with 72 ppm of tantalum (88 ppm of Ta_2O_5), and 57 million tonnes of inferred resources with 62 ppm of tantalum according to the Canadian NI 43-101 reporting code (76 ppm of Ta_2O_5) (Strategic Minerals Europe Corp, 2022).

Reserves of second producing tantalum mine – the Imerys kaolin mine in Echassières in France are not public (Schwela, 2019). The main tantalum bearing mineral in the kaolinized granite are microlite and tantalocolumbite.

Most of the discovered European tantalum mineralisation, are associated with evolved granites, granitic pegmatites and associated aplites which occur in the Palaeoproterozoic rocks of the Fennoscandian Shield and rocks of Variscan orogen in the continental Europe and Ireland (Reginiussen et al., 2021).

Mineral deposits and occurrences in EU that contain tantalum (and niobium) are reported from Finland, Sweden, Greenland, Portugal, Spain, France, Germany, Czech Republic and Romania (Reginiussen et al., 2021)

Beside already mentioned projects a more developed exploration projects with resource estimation in EU are listed in Table 9.

Elu et al. (2021) state that known tantalum resources of Finland amount on 477 t, Greenland on 1,093,147 t and Sweden at 68 t. Contrarily, Lauri et al. (2018) states that tantalum resources in Finland comprise of minimum 12,786 t Ta metal.

Table 9. Estimated EU resources in tantalum.

Deposit name	Company	Country	Host rock	Resources
Alberta II	Strategic Minerals Europe Corp	Spain	Pegmatites	12.3 Mt with 0.0121% Ta_2O_5, 0.044% Sn, 0.204% Li (Bourgeois et al., 2017)
Motzfeldt	Stallion Resources	Greenland (Denmark)	Syenite	340 Mt with 0.19% Nb_2O_5, 0.012% Ta_2O_5, 0.46 % ZrO_2 (Bourgeois et al., 2017)
Rosendal – Kemiö Island	-	Finland	Pegmatites	1.3 Mt at 0.021 % Ta, 0.014 % Be and 0.08 % Sn (Olivera et al., 2021)
Sokli	Finnish Minerals Group	Finland	Carbonatite	250 Mt of at 0.21 % Nb and 0.005 % Ta

Furthermore 13,670 t of tantalum resources are reported at the Krásno and Cínovec area, Czech Republic, with recoverable tantalum contents in experimental tin and tungsten concentrates and 57 t of tantalum historical prognostic resources at the Hůrky locality (Starý et al., 2021). Lauri et al. (2018) describe French tungsten-lithium-tantalum deposits the Tréguennec deposit, with 1,950 t of Ta_2O_5 and 1,860 t of Nb_2O_5 estimated resources and the Les Montmins deposit, which contain 24,000 t of Ta_2O_5.

According to the Reginiussen et al. (2021) the most promising areas for tantalum exploration in EU (which has also the largest number of known deposits and occurrences) are:

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- The Variscan Galicia-Centro Iberian Pegmatitic Province including the Central-Iberian Zone (CIZ) and the Galicia Trás-os-Montes Zone (GTMZ).
- The Massif Central and Armorican massif of France.
- The Fennoscandian Shield with rare element granites, granitic pegmatites and aplites as well as carbonatites.
- Greenland (carbonatites in the W and alkaline igneous rocks in the S and E).
- Bohemian Massif
- The Eastern Carpathians especially in Romania (alkaline igneous rocks)

The identified deposits and occurrences in Europe are available also on EGDI web viewer. Lauri et al. (2018) reports also of tantalum occurrences in Austria, Bulgaria, Italy and Slovakia but majority of those have only mineralogical significance.

GLOBAL AND EU MINE PRODUCTION

According to the WMD global mine production of tantalum between 2010 and 2020 ranged from 799 t (2010) and 2,260 t (2017) (Figure 13). Data from USGS for the last 10 years approximately comply with the WMD data (Figure 14). Before that, USGS reported 3 times higher tantalum production which has most probably methodological reasons.

Main producing countries of tantalum are Democratic Republic of Congo, Rwanda, Brazil, China, Nigeria and Mozambique. Until 2008 Australia used to be the most important supplier of tantalum, but its production decreased significantly and now accounts only minor share in global production. The highest rise of tantalum production the last decade is observed for Democratic republic of Congo.

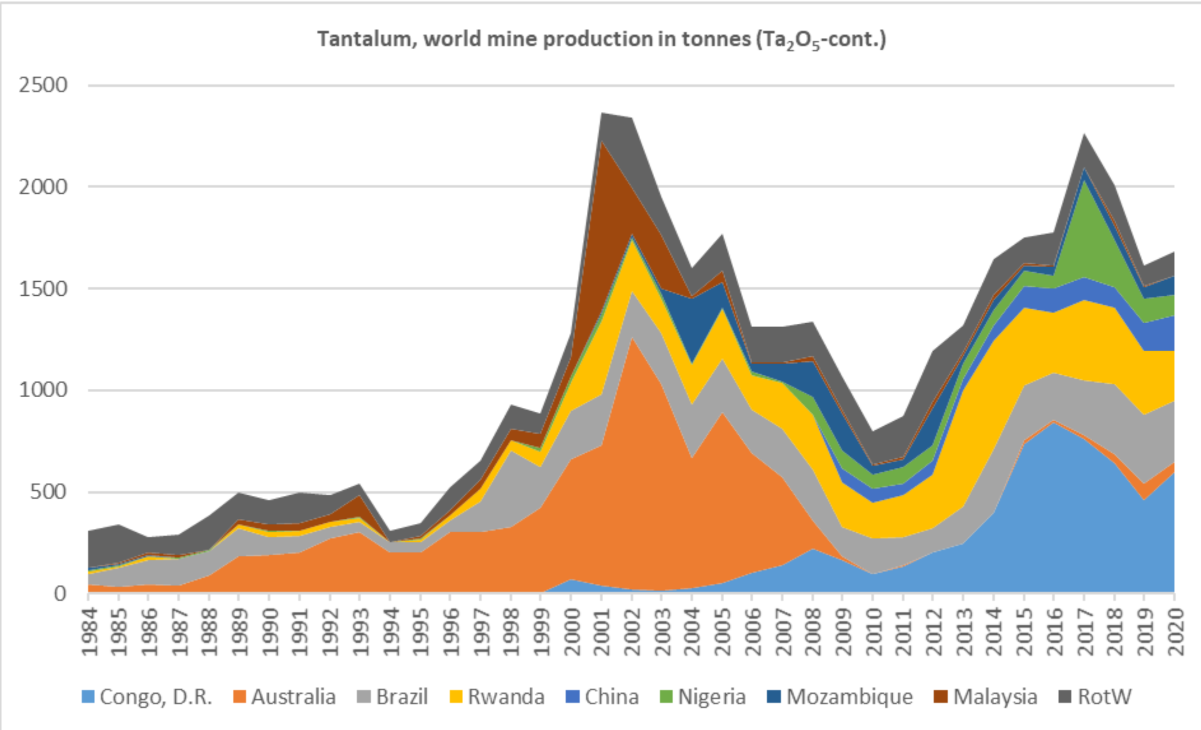

Figure 13. Global mine production of tantalum in tonnes (WMD 1984-2022)

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In Europe only Imerys kaolin mine in Echassières, in France produced minor quantities of the synthetic concentrate (between 4.5 and 6 t) which was exported completely (Bourgeois et al., 2017 and Matos et al., 2021).

Due to the Penouta open pit mine in NW Spain, which is operational since January 2022 also EU will soon be an important producer of tantalum. In first five month of operation 29.8 t of tantalite/columbite concentrate with 17-19% of tantalite and 19-21,5 % of columbite was produced (Strategic Minerals Europe Corp, 2022).

In 2012-2016, China and Burundi imposed export tax for HS 26159090 "Other", the following products are under this HS code: 2615909010 "Niobium, tantalum concentrates and ores" and HS 2615909090 "Vanadium ores and concentrates". Rwanda applied "fiscal tax on exports" of 4% on HS 261590 "Niobium, Tantalum & Vanadium Ores & Concentrates" for which the tantalum concentrates and ores was included.

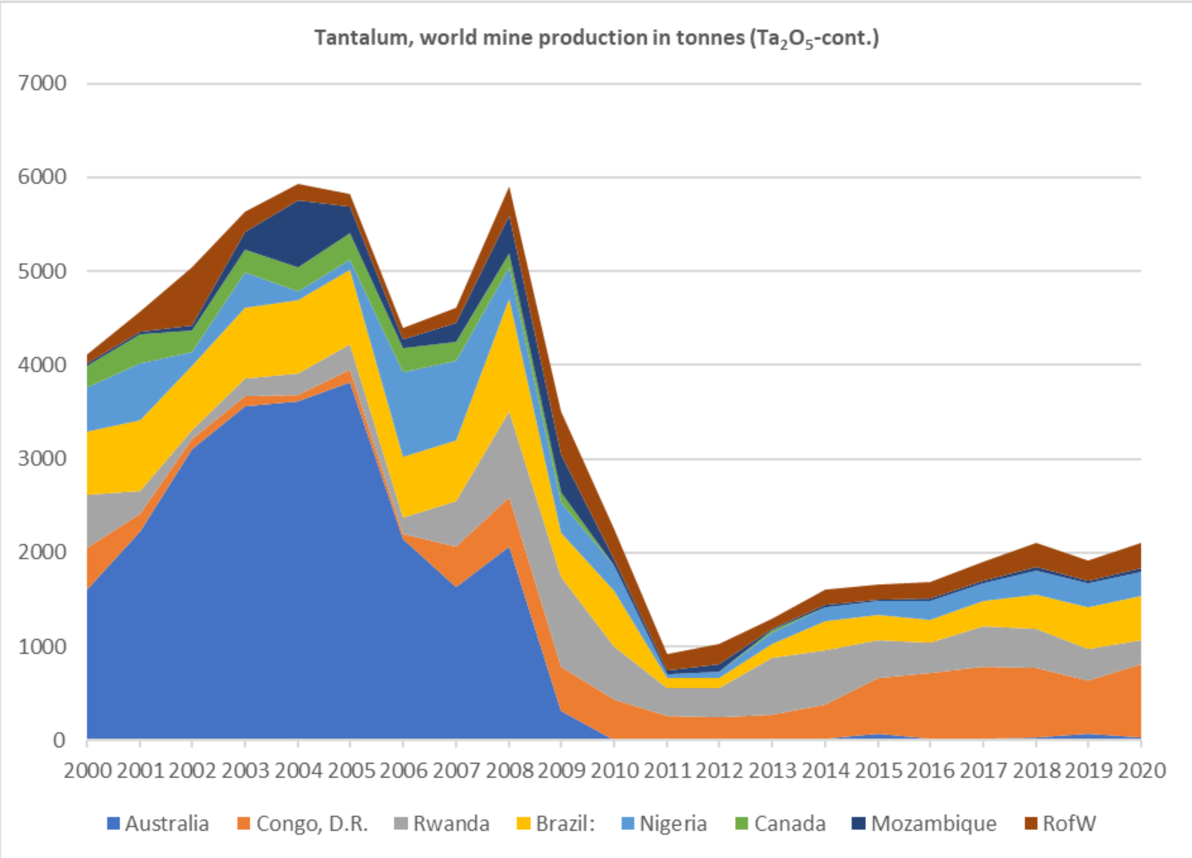

Figure 14. Global mine production of tantalum in tonnes (USGS, 2000-2022)

OUTLOOK FOR SUPPLY

The future supply of tantalum is highly dependent on the development of the lithium projects around the globe, as are tantalum minerals commonly associated with lithium in pegmatites and greisen. As long as transition towards the green mobility will drive the lithium demand on the world market, there will be numerous opportunities to extract tantalum concentrates along with lithium ones.

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Tantalum is also inevitably connected with niobium, tin and partially tungsten mining operations where is frequently extracted as a by-product or is extracted form tin slags. Tantalum supply will be therefore also driven with demand for tin and niobium. However, current situation on global market indicates rise in demand for all of those three raw materials.

DERA (2018) developed two models of the future supply of tantalum from 2016 to 2026 – one optimistic with approximately 168 t of supply surplus in 2026 and one conservative with alarming 321 t deficit of tantalum. The predicted annual growth in tantalum demand was predicted on 3.3 % - the demand for tantalum 2026 would exceed 2500 t/year.

Currently we are closer to the optimistic model where surplus of tantalum supply is predicted due to the development of the major lithium mines such as Greenbushes, Wodgina, Pilgangoora and Bald Hill in Australia and extensions of the Pitinga tin mine and Mibra tantalum-lithium mine in Brazil as well as increased artisanal mining Africa. With exception of the extension of the Pitinga mine (which is still in production) most other predictions fulfilled, meaning that Australia might again become an important supplier of tantalum. Combined with economic impacts Covid-19 lockdown which decreased tantalum demand (and production), shortage of tantalum supply is not expected despite the fact annual production of tantalum will not exceed 2500 t until the 2026.

A reasonable prediction is also that EU will soon receive domestic supply of the tantalum. Penouta mine in Spain, which is in operation since January 2022 could supply up to 100 t of tantalite/columbite concentrate per year. Within also few lithium projects which have potential for tantalum recovery EU are being developed – e.g. Cinovec project in Czech Republic and Zinnwald-Lithium project in Germany.

European suppliers of tantalum are obliged to follow EU Conflict Minerals Regulation, which means responsible sourcing of the tantalum raw materials. Democratic Republic of Congo, which is one of the main producers of tantalum in the world is on the list of conflict countries.

PROCESSING

Primary tantalum ore is processed in following sequence (Bourgeois et al., 2017):

- Crushing (jaw, cone or impact crusher) to fraction below 15-20 mm
- Grinding (ball or rod milling) and classification (screens and hydrocyclones) in closed circuit to below 1 mm.
- Conventional (jig, shaking table), centrifugal (spiral) and enhanced gravity separation (MGS, Falcon concentrator), depending on the size of the liberated particles. The gravity separation takes advantage of the high density of the Ta-bearing phases, with specific density in the range 6 to 8.
- Selective reverse flotation to concentrate the finest material
- Low and high intensity magnetic separation to remove companion magnetic phases.
- Thickening circuit to recycle the process water

Known processing issues are production of unrecoverable Ta ultrafine fractions which are lost to the tailings, presence of the radioactive mineral phases and high costs due to high consumption of flotation additives (which can present also an environmental risk)

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The main processing pathways of the primary tantalum concentrates and tantalum scrap to produce refined material used for manufacture of end products are presented on Figure 15.

No data was available for global and European production of processed materials (Ta oxides and fluorides). WMD, BGS and USGS reported tantalum production only at the extraction stage. There is no Eurostat trade code for tantalum oxides and fluorides in ProdCom and in Eurostat-Comext.

The world production of intermediate products is not known. T.I.C (2019) reported an estimate of 2,200 tonnes of Ta_2O_5, K_2TaF_7, as well as secondary products are generated each year, equivalent to 1,200 tonnes of tantalum. The top three producers of tantalum processed materials are China, Germany, and the United States. No exact production shares are available (Schwela, 2019).

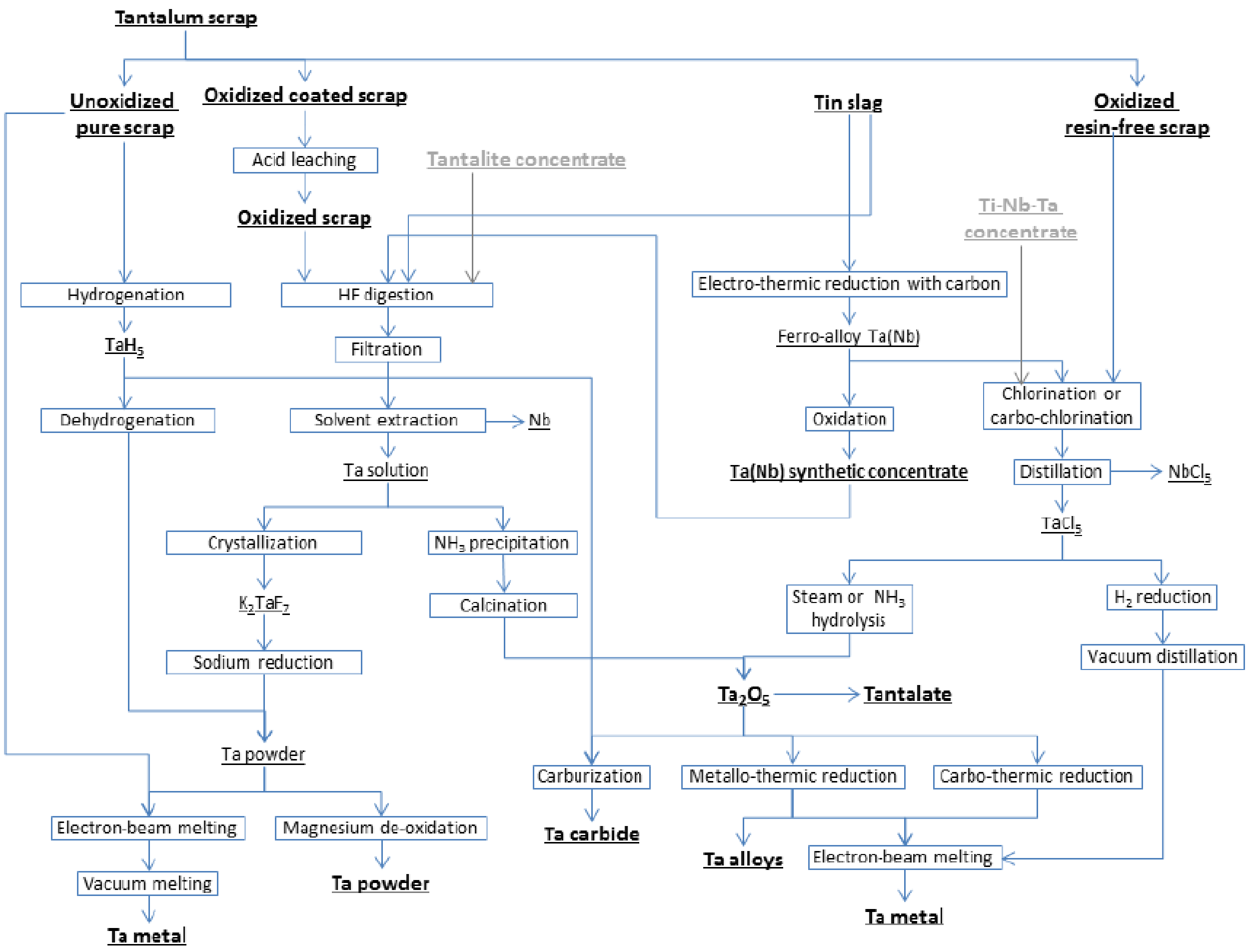

Figure 15. General chart for tantalum production from scrap and primary materials (Bourgeois et al., 2017)

Even though producing countries are quite diverse at the extraction stage, the next steps of tantalum value chain are more concentrated in Asia.

The International Trade Administration (ITA, 2020) reported a list of 37 identified companies known to be able to process tantalum ores and concentrates and produce industrial tantalum products. According to this list,

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18 tantalum processing facilities were located in China. China is the main importer of tantalum concentrates globally and is also a major exporter of processed Ta-products, to the EU, US and others.

SUPPLY FROM SECONDARY MATERIALS/RECYCLING

According to Matos et al. (2021) EU processing sector in 2016 used 164 t of imported secondary raw material and 2 t of imported waste for the tantalum production. Secondary tantalum from domestic scrap (old scrap, new scrap from fabrication of semi-finished products as well as new scrap from manufacturing of finished products, referring to "functional recycling") is also an important input (193 t tantalum content –new 108t of new scrap and 95 t of old scrap) to produce tantalum processed materials (Figure 12).

The collection rate for tantalum products in EU is estimated on 45% in 2016. However, only 15% end of life products was collected and sorted for functional recycling in the EU (85 t). According to Matos et al. (2021) End-of-life recycling input rate (EOL-RIR)) in 2016 for tantalum in EU results in 13%. While the ratio of functional recycling of old scrap and tantalum collected results in 40% (end-of-life recycling rate (EOL-RR).

DERA (2018) estimated the tantalum recycling rate on 30%, where reprocessing of super alloys from aviation industry and sputtering targets form electronic are responsible for most of the recycled material.

Tantalum can be recovered from scrap, incineration bottom ash, superalloys, pyrometallurgical slag, and tin slag following the processes described on Figure 4. Majority of recycling can be considered as 'pre-consumer' that is from within the upstream supply chain itself, rather than from end-of-life products as it can be also seen from the data on Figure 5.

Such example is tantalum recycling from scraps generated during manufacture of Ta containing electronic components, where high recycling rates are achieved. However, no mature technology has been developed to recover tantalum from end-of-life electronic products. Tantalum recycling from post-consumer electronic waste is facing several technical bottlenecks (Kurylak et al., 2016):

- In electronic devices, tantalum is concentrated in components dispersed into PCBs and consequently is difficult to selectively recover and concentrate.
- Tantalum compounds are covered by several layers of minerals (manganese dioxide, MnO_2) and plastics (carbon). This intimate mixing between parts of different chemical composition impedes recycling process to efficiently separate tantalum.
- In addition, during the widely-developed pyro-metallurgical copper route used by e-waste recyclers in Europe (such as Boliden and Umicore), Ta easily oxidizes and migrates into the slag phases.

Example of end-of-life products recycling is the reprocessing of the alloys of turbine blades in aeronautic industry and tantalum carbides cemented in tools.

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OTHER CONSIDERATIONS

HEALTH AND SAFETY ISSUES RELATED TO THE RM OR SPECIFIC/RELEVANT COMPOUNDS AT ANY STAGE OF THE LIFE CYCLE

Tantalum oxide and metallic tantalum, represent a skin, eye and respiratory hazard. In alloys with other metals such as cobalt, tungsten and niobium, tantalum hard-metal dust may cause hard-metal pneumoconiosis and skin affections caused (ILO, 2012).

Occupational exposure limits are set in various countries. The Occupational Safety and Health Administration (OSHA, USA) set the legal limit (permissible exposure limit) for tantalum exposure in the workplace as 5mg/m3 over an 8-hour workday. The National Institute for Occupational Safety and Health (NIOSH, USA) has set a recommended exposure limit (REL) of 5 mg/m3 over an 8-hour workday and a short-term limit of 10 mg/m3 (NIOSH, 2019).

ENVIRONMENTAL ISSUES

Around 20 % to 25 % of tantalum are mined in artisanal operations associated with soil erosion and deforestation. The natural radioactivity of tantalum concentrates and processing waste presents a challenge for global supply chain logistics and waste management (Schütte, 2021).

STANDARDS AND NORMATIVE REQUIREMENTS RELATED TO THE USE AND PROCESSING OF TANTALUM

Tantalum is one of the “conflict minerals” addressed by Directive (EU) 2017/821 („Conflict Minerals Directive“) requiring specific due diligence of importers, and by the (US Dodd-Frank Act, 2010). It is also in the scope of the OECD (2017) “Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas” and the “ASM Code of Conduct” published by (T.I.C., 2022).

SOCIO-ECONOMIC AND ETHICAL ISSUES

ECONOMIC IMPORTANCE OF THE TANTALUM FOR EXPORTING COUNTRIES

According to COMTRADE (2022), the value of tantalum exports does not exceed 0.1 % of the total export values in any of the exporting countries.

SOCIAL AND ETHICAL ASPECTS

Tantalum mining and trade is related to armed conflicts and severe human rights violations and is therefore considered a conflict mineral in legislation (c.f. section “Standards and normative Requirements related to use and processing of the material“). In addition to the conflict minerals issue, 20 % to 25 % of mined tantalum is produced by artisanal and small-scale mining (ASM). ASM often is characterised by vulnerability (limited

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capacity to cope with shocks and hazards) and marginalisation (as it is usually practised in remote areas, with limited access to markets. (Schütte, 2021).

RESEARCH AND DEVELOPMENT TRENDS

LOW-CARBON AND GREEN TECHNOLOGIES

- **Hydrogen production (TRL 4)**

Tantalum oxide and (Oxy)nitrides (TaON and TaN) are attractive light absorbers in photoanodes for hydrogen production by solar water splitting, as well as tantalates, with tunable compositions, thanks to their layered perovskite structure. (Zhen et al., 2016), (Nurlaela et al.,2016). Strong hydrogen demand growth and the adoption of cleaner technologies for its production will enable hydrogen and hydrogen-based fuels to avoid up to 60 Gt of CO_2 emissions in 2021-2050 in the Net zero Emissions Scenario, representing 6.5 % of total cumulative emissions reductions (IEA, 2021).

- **Energy storage systems (TRL 4)**

Lithium-ion batteries are a critical component in order to switch to electrical transportation which requires, however, cobalt, a critical material partially mined under questionable conditions. A potential pathway around the use of cobalt are electrochemically inactive Group 5 metals of the periodic table (vanadium, niobium and tantalum) to design improved battery products. A possible solution could be tantalum-doped Ni-rich oxide ($LiNi_{0.865}Co_{0.095}Al_{0.04}O_2$) cathodes which contain a very small percentage of Co (Li et al., 2022) and the tantalum-doped lithium titanate ($Li_4Ti_5O_{12}$) cathode (Guo et al., 2015). Lithium-ion batteries are at the heart of the electric vehicle (EV) revolution. As such, they are a critical component in reducing the carbon footprint from transportation.

OTHER RESEARCH AND DEVELOPMENT TRENDS

- **TARANTULA[4] project (2019 – 2023)**

The EU-funded H2020 TARANTULA project aims to recover refractory metals tungsten, niobium and tantalum from low-grade waste by developing a suite of cost-effective, scalable and eco-friendly metallurgical processes. Following systematic research activities at a laboratory scale, the new technologies will be brought to technology readiness level 5, and based on performance will be validated at prototype level.

- **OptimOre[5] project (2014 – 2018)**

Only 1 % of the tantalum world production is concentrated in the EU.
The OptimOre project researches and develops models and control technologies using advanced sensing and advanced industrial control by means of artificial intelligence techniques, for the more efficient and flexible tantalum and tungsten ores processing from crushing to separation processes.

[4] See https://cordis.europa.eu/project/id/821159
[5] See https://cordis.europa.eu/project/id/314252

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- **ReFraM[6] project (2015-2017)**

Refractory metals (tungsten, tantalum, rhenium, molybdenum and niobium) exist in the EU mainly as secondary resources (industrial waste, urban mines). Valorizing these resources requires coordination and networking between researchers, entrepreneurs and public authorities to harmonise technologies, processes and services, develop standards, create new potential for export of eco-innovative solutions and for seizing new markets. REFRAM will create a common multi-stakeholder platform that will identify potentials to innovate the value chain of refractory metals with expertise covering the whole value chain including mining, processing, recycling, application. ReFraM will thus optimise the use of external resources like energy and water and contribute to reduce amounts and toxicity of waste, and improve the availability of these refractory metals.

- **SOLCRIMET[7] (2016 – 2021)**

Increasing the levels of critical metal recycling from pre-consumer, manufacturing waste and complex, multicomponent end-of-life consumer products is considered as arguably the most important and realistic mitigation strategy. SOLCRIMET developed a ground-breaking, novel approach called "solvometallurgy" to extract specific critical metals, i.e. rare earth elements, tantalum, niobium, cobalt, indium, gallium, germanium and antimony. The approach involves the discovery of immiscible non-aqueous solvent pairs that allow the extraction of metal complexes at moderate temperatures, leading to high-purity recycled metals. The main outcomes of the project will be lab-scale demonstrators that show the enhanced efficiency, utility and applicability of the new solvometallurgical process.

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[6] See https://cordis.europa.eu/project/id/688993

[7] See https://cordis.europa.eu/project/id/694078

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