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BRIEF REPORT

Save the giants: demand beyond production capacity of tantalum raw materials

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Abstract

Tantalum's high melting point and ability to store and release electrical charges have attracted high-tech companies since its usage in capacitors began in the 1930s. During the COVID-19 pandemic lockdown, daily life relied on electronic equipment, resulting in a surge in demand for electronic and communication gadgets, which could necessitate many tantalum raw materials and an assured supply chain. Despite tantalum's high demand from electronic manufacturers, 5G network systems and electric vehicles are currently added to the tantalum consumer list. The authors have examined three interconnected issues linked to tantalum supply interruption, which has resulted in a growing tantalum scarcity: (1) rising demand for tantalum ores and high-tech equipment while mining activities are in decline owing to the COVID-19 pandemic; (2) tantalum ore price volatility constrains the ore supply chain; (3) the challenge of pandemics that shrink mining activities and handicap supply chain. To address the issue of supply shortage in the long-term, the authors suggest that the concerned parties may adopt new norms of reliable, stable, and transparent supply channels instead of relying on an old uncertain and volatile supply system. The authors also suggest the transformation of central African artisanal and small-scale mining (mainly in Rwanda and the Democratic Republic of the Congo) into a modern mining system with a new supply channel that can resist existing and future disruptions.

Keywords Tantalum · Mineral supply chain · Electronic · Capacitor · Central Africa · COVID-19

Introduction

Tantalum was first extracted and described in 1802 (Baccolo 2015), and it is listed among critical minerals by many industrialized countries (Mancheri et al. 2018) due to its politically sensitive origin and uses (Vidal et al. 2013). Its essential properties of high melting point (Lim 2016) and ability to efficiently store and release electrical charge have made it a super wanted element for highly specialized applications of industries (Nassar 2017), including that of electronic devices (most known) (Barume et al. 2016; Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development 2017), automotive, aerospace, chemical processing, defense, medical, and metallurgy (Nassar 2017), etc. It is mainly used in capacitors (Schütte and Näher 2020), and the first tantalum capacitor was developed in the 1930s for military purposes (Tailor 1969; Albrecht et al. 2011). Its applications expanded its global exploration and extraction.

Since 2006, tantalum's global production source gradually shifted from Australia to central African countries, mainly in Rwanda and the Democratic Republic of the Congo (DRC)

Highlights
1) Rising demand for tantalum raw materials and high-tech products while mining activities decline.
2) Tantalum ore price volatility contributes to the handicap of the tantalum supply chain.
3) The challenges of pandemics shrink mining activities and disrupt the supply chain.
4) Tantalum supply chain may adopt new reliability, stability, and transparency norms to ensure a long-term sustainable supply.

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(Sanderson 2015). Though central Africa is composed of about 12 countries, only Rwanda and DRC produce a significant amount of tantalum, Burundi produces a low quantity, and others have no records of tantalum production. However, even if these two central African countries have been the main producers for over a decade, other countries such as Brazil, China, and Australia produce considerable tantalum (Fig. 1). Since the production shift of tantalum ore production, the world of technology has depended on tantalum from central Africa. This is due to its production of more than 50% of global tantalum from 2009 to the present (Fig. 1). It is estimated that the electronic industries have consumed 70% of 2021 total demand, which equals 5.5 million pounds of tantalum ores and concentrates. For the past three decades, the tantalum consumption of electronic industries has been relatively high as it counted between 50 and 70% of global tantalum demand (Zogbi 2021a). Due to the recent advancement in technology, the demand for those industries has significantly increased.

Recently, the tantalum market experienced swings, especially during the COVID-19 pandemic, where disruption in demand, production, supply chain, and pricing became a significant challenge to tantalum consumers. Because artisanal and small-scale mining (ASM) is the extensive method used in Rwanda and DRC mining (Macháček and Dušková 2016; Mancheri et al. 2018; Macháček 2019, 2020), the restrictions of COVID-19 kept their workers at home without production. Thus, those unpredicted disruptions caused by lockdowns and curfews did not leave the metal supply chain unshaken. During this period, electronics were the first reliable materials to depend on, triggering high demand for electronics while mining activities were shrinking. The high demand for electronics is not only accompanied by tantalum price increases but also requires high tantalum raw materials production.

The strict measures, including temporary mine closures in Brazil and Rwanda during the fight against the pandemic, have decreased global production (U.S. Geological Survey 2021). The estimate of 2020 production of the above two countries and DRC was 77% of the global output (U.S. Geological Survey 2021). However, as a new wave of COVID-19 outbreaks, countries like Rwanda imposed multiple lockdowns than expected (Musanabagnwa et al. 2020; Butera et al. 2021), which in return decreased the production significantly from 336 tons in 2019 (U.S. Geological Survey 2021) to 254 tons in 2020 (U.S. Geological Survey 2022) equivalent to 24% decline.

It is still uncertain when the mining activities will be back in their normal state due to two big reasons: (1) COVID-19 variants that hardly hit the African continent in terms of economy (Taylor 2022) and (2) the low vaccination rate in central Africa that is the extensive producer of tantalum. By taking an example of the mining sector, Africa estimates that 9 million people are directly involved in ASM, and 54 million people's livelihoods indirectly depend on ASM (Munyati 2020). However, most ASM activities are informal (Macháček 2020; Munyati 2020) and COVID-19 restrictions kept all those millions at home without another income source. Most of them are young people, and according to Wim Naudé (Naudé 2021), the pandemic consequences will slow down Africa's youth development for a decade and will create long-term socio-economic problems in Sub-Sahara African Region (Fagbemi 2021). This increased the unemployment among youth and raises the risk of tantalum shortage on the market compared to demand and will negatively affect the sufficiency of electronics and automotive manufacturing. This article discusses three inter-correlated points associated with tantalum supply chain disruption and shortage, which can lead to insufficient production of electronics and other high technology materials.

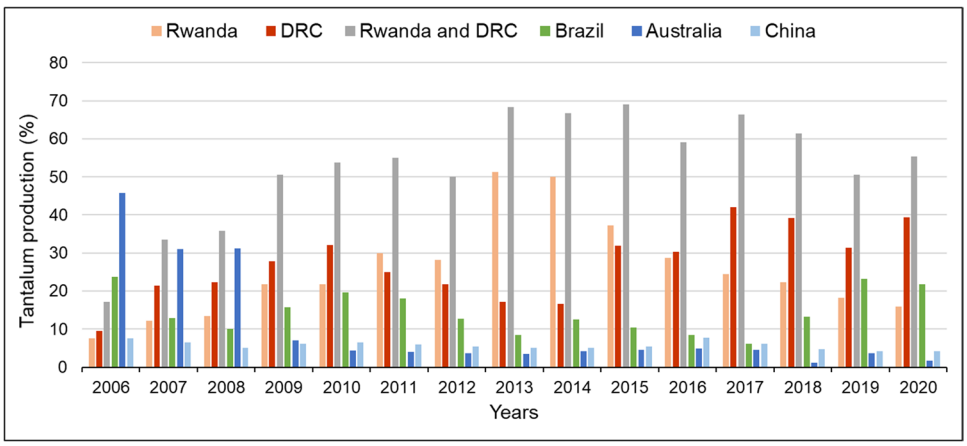

Fig. 1 Global main producers of tantalum. Data source: USGS (U.S. Geological Survey 2022)

Factors linked to tantalum supply chain disruption and shortage

Unprecedented tantalum demand

The tantalum raw materials demand growth can be explained by examining the tantalum applications. First, it is mostly used in alloys and electronic equipment (Baccolo 2015). These electronics and communication devices have proven to be the most potent and useful tools during a COVID-19 pandemic lockdown, whereby daily life depended on electronic devices more than ever; second, the rise of aviation and aerospace industries that need tantalum (Lim 2016); next, manufacturing of small tools such as tantalum wire, powder in superalloys, thin-film resistors, and carbides (Zogbi 2021a); finally, the expectation of rolling out the 5G system that has already started in some countries and manufacturing more electric vehicles than before (Manthey 2020; Stratton and Matheson 2021). Tantalum's durability, robustness, and connectivity properties made it the best metal to expand the use of its capacitors in 5G hardware systems (Stratton and Matheson 2021) and electric vehicles (Stratton and Matheson 2021; Magdalena et al. 2022) as the new generation technology of focus after the pandemic (Manthey 2020).

The recovery from the pandemic made the sectors mentioned above that use tantalum rush on resuming activities and conquer the limited tantalum raw materials on the market. The speed of increasing production of raw materials seems to be low compared to the growth of industrial sectors that need tantalum. Despite the production shrunk of some aircraft manufacturers and vehicle producers (Akcil et al. 2020), they will add insult to the injury once they get into full operation. Additionally, in the race of human beings to connect everyone and everything virtually, rolling out a global 5G network is an inevitable race and will require massive tantalum. Satisfying this market demand should be prominent; otherwise, the consideration of alternatives to reduce the shortage of tantalum capacitors must be enhanced.

Tantalum ore pricing

Between 2018 and 2019, two Australian companies produced byproduct tantalum concentrates from lithium operations, and one Estonian company produced tantalum from recovery operations. Those tantalum byproducts were low-cost and significantly declined the market price (Fig. 2a). Unfortunately, after some time, all three companies suspended their plans that produce tantalum due to different reasons (Abraham 2020). That price decline forced many large mines to close. The imbalance in demand, supply, and consequent decline in price is also attributable to the over-dependence of unaccounted materials from Central Africa traded below market price. The price decline is also related to prevailing global market conditions, affecting the entire mineral sector (Mancheri et al. 2018).

In early March 2020, more than 100 countries recorded coronavirus and started to impose partial or complete lockdowns (Musanabagnwa et al. 2020). Even if the duration of lockdowns differs from country to country (Guan et al. 2020), the unprecedented lockdowns and temporary closure of mines, factories, and borders destabilized the global supply chain (Akcil et al. 2020). Industries and manufacturers that were using tantalum raw materials were also temporarily shut down; the aviation sector that was rising in consuming tantalum suspended its services (Agrawal 2021; Yu and Chen 2021) and stopped new orders; thus, the declining price of tantalum about $20 (Fig. 2b).

China was the first country to impose a lockdown (Guan et al. 2020) and became a role model in implementing measures to fight against the spread of COVID-19 (Musanabagnwa et al. 2020). China as the largest global consumer of

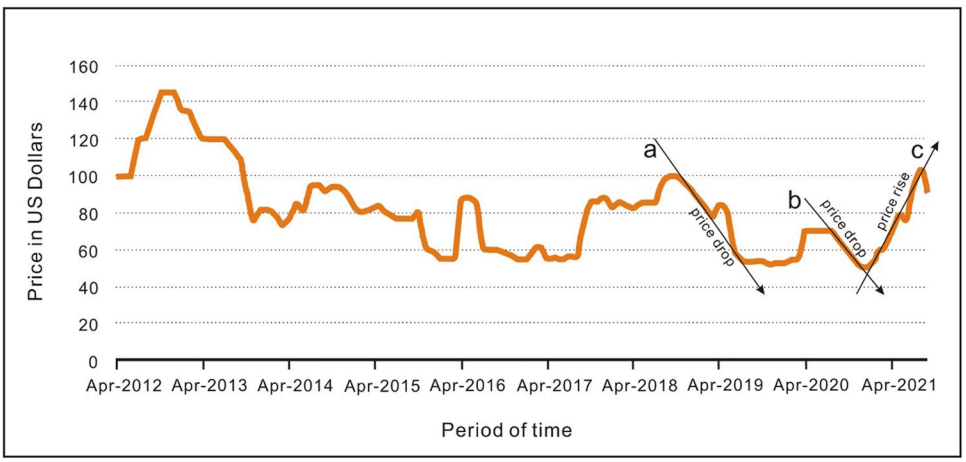

Fig. 2 Tantalum ore pricing trend by month in US dollars per pound from April 2012 (Zogbi 2021b); **a** decline of the price before the pandemic, **b** decline of price during the pandemic, **c** increase of price of after lockdowns

metals, together with other mineral importing and exporting countries, imposed tough measures to stop the spread of coronavirus, so their lockdown and closing of borders suspended imports of raw materials and caused the price to decline (Zhu et al. 2021).

The dependence on electronic and communication devices during COVID-19 lockdown has shown the full importance of technology in daily life. This dependence opens many people's minds and awareness of technological tools' usefulness, and many orders have been placed despite the lockdown. As soon as the pandemic restrictions eased, including resuming industry and factory work, it immediately triggered a sudden need for a large number of raw materials.

Since most countries completely removed pandemic restrictions and resumed most of their activities, all manufacturers and industries needed raw materials to resume their operations. The raw materials required by factories and manufacturers are limited on the market due to the supply shortage, thus doubling the price between January and August 2021 (Fig. 2c). This may be attributed to the variation of the COVID-19 pandemic (Ulrich et al. 2021) that creates instability in mining activities and the supply chain, pushing prices to jump from $50 to $105 within 8 months of 2021.

Challenges of tantalum ore supply

By talking about tantalum ore production, we cannot leave without pointing to central African countries that the world has relied on for decades. Since 2009, central African countries have been producing more than 50% of the world's tantalum in ore and concentrate. The spread of the COVID-19 pandemic forced governments to lockdown in central African countries to control the spread of the pandemic (Manthey and Cristina 2020) and contributed much to the tightness of supply due to the concerns of obtaining materials. For instance, from March 2020, Rwanda committed to protecting the miners' health from contracting coronavirus by completely suspending all mining activities (Munir 2021). Coronavirus and the already existing problems affecting the tantalum supply chain created worries of uncertain future availability of raw materials on the market. They made the buyers struggle to get cheap materials. Though price increases, the appetite for buying never ceases amid limited supply (Stibbs 2022). However, the COVID-19 pandemic that temporarily closed mines, factories, and borders (Guan et al. 2020) and disturbed the African mineral supply chain (Akcil et al. 2020) has created a chaotic situation in the global mining industries such as losing billions of US dollars (Azevedo et al. 2020). According to Andrzej Gała´ (Gałas et al. 2021), the import–export of materials used for mining operations was interrupted, and the persisting of COVID-19 threatens to cause permanent disruption of the raw materials supply chain. It is critical to highlight that it could further complicate the puzzle for high tech-giant to satisfy consumers due to a shortage of tantalum-capacitor chips and alloys linked to the shortage of tantalum ore production.

In recent years, COVID-19 is the only pandemic that threatens global human beings and, at the same time, destabilizes the global supply chain. It created panic among the governments and population, making people believe that vaccines could be the hope of escaping the chaotic pandemic situation (Porat et al. 2021). This can be explained by the vaccination passports policy (De Figueiredo et al. 2021; Hall and Studdert 2021; Porat et al. 2021; Sharun et al. 2021) implemented by governments to (1) restrict unvaccinated people to stop the spread, (2) give freedom of travel to vaccinated people, and (3) encourage unvaccinated people to take vaccine (Porat et al. 2021). Unvaccinated people were not allowed free movement (Voo et al. 2021) and do not have access to public spaces or workplaces and were banned from international travel. This restriction policy prevents unvaccinated people to return to jobs which slows down production and supply. It is believed that the economy will gradually recover after vaccinating the majority of the population (Sharun et al. 2021) because all activities, including mining and the mineral supply chain, can resume as pre-pandemic. However, coronavirus made it worse even if the tantalum supply chain has been suffering from many factors (such as geopolitics, conflicts, and militias). It kept people in a dilemma of when the supply chain can recover to a normal state in the tantalum producers, especially on the African continent that produces 70% of global tantalum (U.S. Geological Survey 2022) in which a vaccination rate remains significantly low at 7% (Adepoju 2021). The DRC, as an extensive global producer of tantalum vaccination, is less than 1% of its population (Adepoju 2021).

Taking an example of Rwanda, according to USGS data for 2021 and 2022, when the vaccination rate was 0% in 2020 (WHO Africa 2021), the tantalum production declined 24% compared to 2019 due to the tough restrictions, but at a 40% vaccination rate (Tasamba 2022), production decreased only 5% compared to 2020 due to the removal of restrictions and resuming operations. Though the global tantalum reserves are more than enough and estimated to be sufficient probably in the coming 500 years (Mancheri et al. 2018), the struggles to get enough production come one after another. Among those struggles that hinder enough production are linked to (1) conflicts in the region of tantalum origin (Resolve 2010; Metal Powder Report 2012; OECD 2013; Cook and Mitchell 2014; Sauer and Seuring 2017; Hofmann et al. 2018; Schütte and Näher 2020), which triggers the increase of international rules and regulations on tantalum mineral trading; (2) frequent epidemics such as ebola (Rohan and McKay 2020) simultaneously with coronavirus (Musanabagnwa et al. 2020), diarrhea (McQuilken and Perks 2021;

Roman and Fwasa 2021), and malaria (Smith 2011; Roman and Fwasa 2021) that outbreak in the DRC negatively affect mining and supply chain inside the country which make the country to be isolated; (3) militias and other armed groups (Prendergast 2009; Blore and Smillie 2011; Nick 2014; Callaway 2017; Macháček 2020) that intervene in DRC illegal mineral trade; and (4) price fluctuation (Fortier et al. 2018; Mancheri et al. 2018; Schütte and Näher 2020) discouraging investors, miners, and mineral traders. Even if the pandemic that significantly handicaps the global mineral supply chain still exists, the progress of the mineral supply chain recovery is close to the pre-pandemic normalcy. Furthermore, the fear and consequences of a pandemic are far from over.

Prospect of post-COVID-19

The mining sector is the key sector that contributes to modern digital technologies. The post-COVID-19 pandemic is going to be marked by an advancement in technology than before. 5G hardware systems and electric vehicles are among the new tantalum consumers to compete in the tantalum raw material market. Their demand adds to that of semiconductors that are also suffering the shortage due to supply chain issues (Manley et al. 2022). So, to ensure the long-term sustainability solution to tantalum's increasing demand, the supply chain may adopt new norms of reliability, stability, and transparency instead of continuing uncertainty and volatility in supply. The parties involved in the tantalum supply chain (countries of origin, suppliers, and manufacturers) may agree on the supply chain channel that could secure supply. For example, different series of transformations may apply, including the transformation of ASM into modern mining in central Africa; adding exploratory and new discovery data to production, import, and export data during the quantification of the future sustainability of the tantalum supply chain.

Conclusion

The growth of the tantalum market demand is interpreted based on raw tantalum materials that are needed to satisfy the market. Despite the existed disruption of the supply chain linked to the unsteady supply–demand from central Africa, the COVID-19 pandemic that temporarily closed borders has worsened the instability of the supply chain and triggered price fluctuation. Apart from the existing tantalum main consumers that are currently in high demand such as electronics, 5G hardware systems and electric vehicles are among the new consumers of tantalum that stimulate post-COVID-19 high demand. This increases the risk of a supply shortage due to the slow speed of mining recovery compared to the speed of demand growth. To ensure a long-term solution, the concerned parties may adopt new norms of reliability, stability, and transparency instead of relying on an old uncertain and volatile supply system. Among the suggested solutions, it includes transforming central African ASM into a modern mining system with a new supply channel that can resist the existing and future disruptions.

Abbreviations *5G*: 5Th generation; *DRC*: Democratic Republic of the Congo; *ASM*: Artisanal and small-scale mining; *USGS*: United States Geological Survey; *$*: United States dollar; *US*: United States

Author contribution The authors of this manuscript have equal contribution.

Declarations

Conflict of interest The authors declare no competing interests.

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