Essential Minerals for the Green Revolution – 6 “The Three Ts”
Tin, Tungsten and Tantalum

Three important silvery-looking metals - tin, tungsten and tantalum - often occur together, and their English names all begin with the letter “T”, even if their chemical symbols don’t! Another silvery-looking metal, niobium, often occurs in close association with tantalum, so it is included in the table below. (The old name for niobium is columbium and its main ore is columbite, so the combined ore is nicknamed “coltan”).
The ores of the three Ts and niobium occur in very coarse-grained granitic rocks, known as pegmatites, and in veins running through older rocks. When the pegmatites and veins are eroded, the products are washed down in rivers and even into the sea, and become deposited. All the ores of these four metals are much denser than quartz sand and they may become concentrated as placer deposits (Relative densities of around 7 compared to around 3 for sand).
The main ores are shown in the photo (Fig 1)

Fig 1. Ores of the “Three Ts” and gold: clockwise from top left: coltan (Ta and Nb); cassiterite (Sn), gold (Au) and wolframite (W)
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Mining is carried out on all scales from vast mechanised mines to very small-scale ones: some of these are licensed, but many are illegal. The small mines are worked by local people, known as artisanal miners, under dangerous conditions and with little return for their money.

Fig 2. An artisanal miner in the DR Congo grinding coltan ore by hand
(*Photo courtesy of AdobeStock* 277349036*)*

In some countries, e.g. the eastern parts of the DR Congo and in Columbia, criminal gangs try to control the mining and people have been killed or forced to leave their homes and even their country as a result. The 3T minerals plus gold are often referred to as “conflict minerals”.
However, many of the bigger mines are run by large companies who try to work the ores responsibly, licensed by the local authorities and with care for the environment and for the needs of the local people.

Where the ores have formed placer deposits in large rivers and in the sea they may be extracted by dredging up the sands and separating the ore. The unwanted sand is then deposited behind the dredger as it moves forward. For example, Indonesia, which is the world’s second largest producer of tin, obtains about 60% of its tin in this way. The huge scale of such operations is shown in Figure 3.

Fig 3. A tin dredger in Indonesia (*Photo courtesy of PT Timah Indonesia*)

- Suggest some of the advantages and disadvantages of dredging for tin ore in the sea, compared to mining it in big open pits and mines on the land. (*Dredging takes place away from people's homes, so they are less disturbed; no blasting is needed and no dust created; it is on the coast, so cheaper sea transport can be used for the product; the sea bed is disturbed and the tailings need spreading carefully to reinstate the environment; coral reefs may be damaged*).
- Suggest how a responsible government might ensure that problems are overcome. (*Only award mining licences to companies which show that they are following the UN Sustainable Development Goals; promote good practice in restoring open pit mining areas on land by planting new forest trees, cleaning up water supplies and improving the environment for wildlife; only permit dredging operations away from coral reefs and from tourist beaches; create extra reefs and fish shelters artificially after dredging has happened and plant mangrove trees.*

Unlike lithium and cobalt etc, the 3Ts are mostly not used directly in energy-saving equipment or transport, but they are vital to the engineering industries which manufacture these things.
For a brief view of the world scene, ask pupils to look at the table and answer the questions which follow.

Metal	Symbol	Atomic number	Uses	Main mine production countries in tonnes in 2022
Tin	Sn	50	Alloys for solder and bronze; electrodes for lithium-ion batteries; alloyed with Nb for magnets for MRI scanners; tinplate for "tin" cans; molten tin is used to make sheets of "float" glass;	China 95,000 Indonesia 74,000 Burma (Myanmar) 31,000 Peru 20,000 DR Congo 26,000
Tantalum	Ta	73	Electronics e.g. mobile phones & car computers; surgical implants and prosthetics; electrodes in lighting; special glass lenses; strong alloys with steel for aerospace industry.	DR Congo 860 Brazil 370 Rwanda 350 Nigeria 110 Australia 57
Tungsten	W	74	Combined with carbon to make tungsten carbide for cutting and drilling metals and masonry and for tiny drill bits for drilling in electronic circuit boards; alloyed with other metals to make arc welding electrodes; tungsten compounds are used in fluorescent lighting.	China 71,000 Vietnam 4,800 Russia 2,300 Bolivia 1,400 Rwanda 1,100
Niobium	Nb	41	Alloyed with steel to make strong blades for jet engines and oil pipelines; superconducting magnets for MRI scanners; Nb in glass increases refractive index, allowing thinner lenses.	Brazil 71,000 Canada 6,500 DR Congo 600 Russia 450 Rwanda 210

- List which of these countries are in Africa and are mostly not industrialised (*DR Congo, Rwanda, Nigeria*)
- List four major industrialised countries (*China, Australia, Russia, Canada*)
- China has low reserves of niobium and is not using much of its huge reserves of tantalum. Which countries are most likely to export niobium and tantalum (i.e. "coltan") to China? (*Brazil, DR Congo, Rwanda and Nigeria*)

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The back up

Title: Essential Minerals for the Green Revolution – 7 “The Three Ts”

Subtitle: Tin, Tungsten and Tantalum

Topic: Contrasting good practice in extracting essential minerals with illegal mining. A brief survey of world production of the “Three Ts”

Age range of pupils: 12 years and above

Time needed to complete activity: 30 minutes, depending on discussion and web searches etc

Pupil learning outcomes: Pupils can:
- explain why more tin, tungsten and tantalum are needed in industry as new technologies are developed;
- evaluate different possible sources of tin, tungsten and tantalum;
- outline how responsible governments can ensure good standards from the mining industry in care for the environment and for local populations.

Context: This activity could be used in a lesson on the need to identify and exploit tin, tungsten and tantalum reserves for use in vital applications in many different fields. Worldwide demand for these metals is rising rapidly as new technologies are embraced. These are not necessarily directly related to carbon reduction, but are needed for the engineering which is, e.g. special steels and strong magnets for wind generators; drilling equipment for carbon capture and storage facilities or ground source heat pumps; energy storage; electronic control and communication systems.

Following up the activity: Pupils could be asked to locate the countries shown in the table on page 2, plot bar graphs of the figures and make their own comments about the result. Small groups could be asked to follow up some of the information contained in the websites listed below, or those of other government agencies or companies.

Underlying principles:
- Worldwide demand for the “Three Ts” and niobium is increasing rapidly with the growth of new technologies.
- Existing technologies also require more of the “Three Ts” and niobium as world population increases.
- Some of the “Three Ts” and niobium can be recycled, but there is insufficient in circulation to be able to supply rapidly growing needs.
- Demand, notably from China, encourages small scale artisanal mining and unscrupulous activity which often lead to conflict and bloodshed.
- Mining of any minerals can cause emissions and water pollution which are harmful to both human health and the environment.
- Responsible governments and companies are leading the way in reducing the harmful impacts of mineral extraction by mining or dredging.
- The UK and Europe have included the “Three Ts” and niobium in their Critical Minerals lists, i.e. minerals which are vital to the countries’ economies but where their own resources are limited or unexplored.

Thinking skill development:
Establishing the worldwide demand for “the Three Ts” and the need to extend the mining of it involves construction. Metacognition is involved when discussion arises over the plight of regions where conflict is involved, and in evaluating methods of reclamation of former areas of extraction. Applying thinking to new contexts is a bridging skill.

Resource list:
- access to the table, images and information above
- an atlas, or the electronic equivalent per group of pupils

Useful links: For related Earthlearningidea activities, see table below and:
https://www.earthlearningidea.com/PDF/69_Riches_in_the_river.pdf
https://www.earthlearningidea.com/PDF/164_Gold_panning.pdf
For teachers: For an example of a major mining company endeavouring to work within the laws of a country:
https://timah.com/blog/sustainability/commitment-to-esg.html
For an example of a country’s need to identify fresh resources of critical minerals: BGS Report, single column layout (ukcmic.org)

Source: Written by Peter Kennett of the Earthlearning idea team. Thanks to Ben Lepley of SLR Consulting Ltd for advice.

Note: This activity was as accurate as possible in summer 2023. Rapid developments are taking place in the technology of low and renewable energy.

Essential Minerals for the Green Revolution

Earthlearningidea has compiled a series of activities on the minerals which are essential if modern technology is to be able to reduce the World's carbon footprint. Some are regarded as "critical" minerals and many of them are relatively "new" in terms of needing to be exploited.
This table will be updated as fresh activities are added.
All titles begin with: Essential Minerals for the Green Revolution…

Mineral	Title
Lithium	1 Lithium: an element which is pulling more than its weight in the world
Copper	2 Copper: an element for which the demand is increasing rapidly
Rare Earths	3 Rare Earth Elements: vital components in modern technology
Graphite	4 Graphite: from a pencil to the electric car!
Cobalt	5 Cobalt: mined by children
Tin, Tungsten, Tantalum	6 "The Three Ts": Tin, Tungsten and Tantalum
Gold	7 Gold: an essential mineral - or is it?
Critical minerals	8 Critical Minerals: Essential mineral - critical mineral: what is the difference?