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Gold mining in the classroom: a lab activity to teach sustainability

Student info sheet

What's inside a smartphone?

What you hold in your hands isn't just a mobile phone; it's so much more. Emails, messaging, apps, the internet: we have everything in one small device that relies on more than 50 chemical elements to work. Each one is essential to power its countless features and functions, making it ever more efficient and high performing. The problem is that within the next three years, you'll replace it. Either because it can no longer update, or because a component that is difficult to replace or too expensive to repair breaks. What will happen to your old phone?

Metals

Smartphones contain dozens of different metals, which account for roughly 45% of the phone's total weight. They can be found everywhere throughout the device: in the screen, the casing, and the electrical circuits. Many of these elements are essential for features we now consider fundamental, such as the touch screen, camera, and haptic feedback (vibration).

Find out more about critical minerals in smartphones.

(*https://www.sfa-oxford.com/knowledge-and-insights/critical-minerals-in-low-carbon-and-future-technologies/critical-minerals-in-electronics/critical-minerals-in-smartphones/*)

The rare earth elements

Rare earth elements are essential in smartphones because their use has significantly reduced device sizes while boosting audio, vibration, display and battery performance. The group consists of 17 elements: scandium, yttrium and 15 lanthanides, with atomic numbers ranging from 57 to 71. Their name should not be misleading: they are called rare because they are spread out in small concentrations across the planet rather than being found in concentrated deposits, not because they are scarce. As a result, extracting them is time-consuming, expensive, and severely polluting to the environment.[1]

The 3TG

Along with tin, tungsten, and tantalum, gold belongs to the **3TG group** – four materials that are indispensable for producing modern electronics.

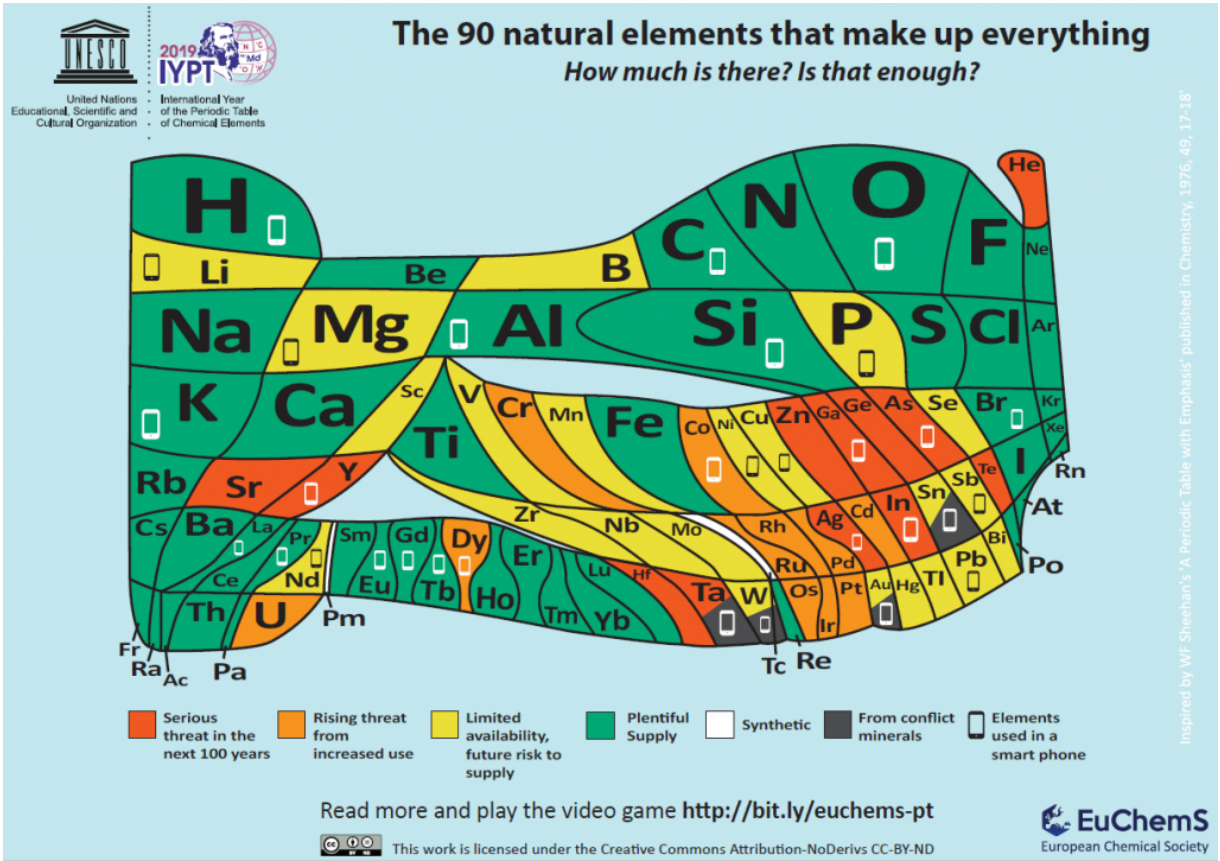
Gold

A typical smartphone contains about 0.03 g of it.[2] Although smartphones contain only small amounts of gold, it plays an important role for circuit boards and microchips because of its excellent electrical conductivity and resistance to corrosion.

Coltan

Coltan (short for columbite-tantalite) is the ore from which the metal tantalum is extracted. Tantalum is used to make tantalum capacitors, tiny components that store and release electrical charge very efficiently in a small space. A single smartphone can contain dozens of tantalum capacitors, making coltan indirectly present in almost every modern mobile device.[3]

These materials are vital to produce the electronic devices we use every day. It is crucial to realise that these are finite resources, meaning they have a limited availability in the Earth's crust.



The periodic table of abundances
Image: EuChemS, CC BY-ND

Questions

- Looking at the table of abundances compared to the standard periodic table, which elements appear enlarged and which ones seem to almost have disappeared?

- Your phone contains lithium (Li), cobalt (Co), copper (Cu), gallium (Ga), indium (In), and silicon (Si). Which of these are represented in larger areas and which are representing in smaller areas on the table?

- If an essential element for computer chips is tiny in the periodic table of abundance, what geopolitical, economic, or practical problems do you think this could cause?

What's behind a smartphone?

Social and human-rights impact

While elements like coltan give our devices their essential high-performance capabilities, the global electronics supply chain carries a high human cost, particularly in regions like the Democratic Republic of the Congo (DRC), which holds a significant portion of the world's reserves.[4]

This issue goes far beyond a single mineral: smartphones rely on a wide range of critical raw materials whose extraction is deeply tied to regional conflict, hazardous working conditions, and severe community disruption. Much of this extraction occurs in conflict zones, where militias and armed groups frequently take control of mining sites or enforce illegal taxation on transport routes. In this way, these revenues are being used to finance violent civil war and perpetuate regional instability.

Beneath this political conflict lies a stark human reality for the workers themselves. The vast majority of these minerals are mined informally through manual work, where workers, including young children, dig by hand without basic protective equipment or safety protocols. Unstable tunnels frequently collapse, and constant inhalation of toxic mineral dust leads to chronic respiratory diseases and long-term health impacts.

The disruption extends to entire populations. The sudden influx of unregulated mining operations often leads to forced displacement, clearing local communities and destroying traditional agricultural economies.

Ecological impact

However, the damage is not limited to human exploitation and health impacts. It extends deeply into the surrounding ecosystems. Mining causes severe global environmental degradation, contributing 4–7% of global greenhouse gas emissions and driving habitat destruction, deforestation, and widespread pollution.[5]

The processing of extracted minerals relies heavily on hazardous chemicals that inevitably seep into the surrounding environment. A prime example is the widespread use of toxic mercury in artisanal gold extraction: mercury binds gold particles, making them easier to isolate; the residue is often discharged directly into local rivers and soil. Mercury that is released into the environment can contaminate crops and aquatic food chains, harming wildlife and humans.[6]

To access underground deposits, vast stretches of land are cleared of vegetation and topsoil. This large-scale land disruption strips ecosystems of their natural cover, triggering severe soil erosion and displacing local wildlife long before processing even begins.

Another point to consider is the average annual carbon footprint of a single smartphone: it costs roughly 60 kg carbon dioxide equivalents (CO_2e) (approximately like 350 km covered by a petrol-fuelled car.[7] Nevertheless, it's important to consider that 80% of a smartphone's lifetime CO_2e emissions are attributed to its production.[8]

First, raw materials must be extracted through mining, a notoriously carbon-intensive process. Afterwards, they often travel across multiple countries to be refined and processed into specialised parts. They are then shipped to manufacturing hubs to be assembled into the final smartphone. Finally, the completed devices embark on yet another journey to be distributed, stocked in stores, and sold to consumers worldwide.

During its daily use, a smartphone also consumes energy and generates CO_2 emissions. Charging the battery, downloading and using apps, making a call, and browsing the internet: each of these common operations requires energy consumption and emits different percentages of CO_2, with an invisible impact on the environment.[8]

Questions

- If we were to open up your phone and trace the origin of every single chemical element, such as lithium from Chile, cobalt from the Congo, or indium from China, what would the geographic map of your device look like?

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- What would happen if a country suddenly decided to block the export of a critical mineral used in microchip production?

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- How many kilometres do you think individual chemical elements travel before being assembled into the final phone you hold in your hand?

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Image: Richard August/Wikimedia Commons, Public Domain

E-waste

If you consider that there are now more mobile phones than people on Earth, and that a typical phone is replaced every two to three years, it becomes apparent how huge the annual flow of electronic waste (e-waste) must be! We could fill enough waste lorries to wrap around Earth's equator, as you can see in the image below.

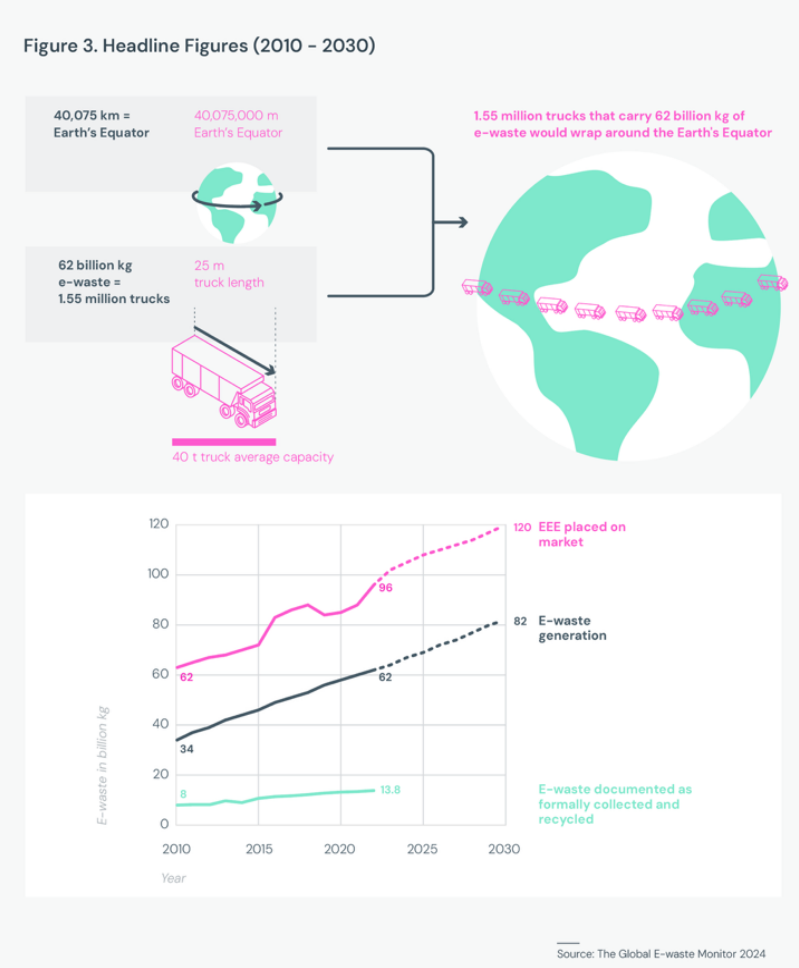


Image courtesy of the Global E-waste Monitor 2024

When we include not only smartphones but also laptops, tablets, TVs, appliances and other devices, it is no surprise that e-waste has become one of the world's fastest-growing waste streams. According to recent UN data, the world generated about 62 million tonnes of e-waste in 2022, an 82% increase since 2010. Estimates project that we will reach around 82 million tonnes by 2030.[8]

A significant share of this waste comes from high-income countries in Europe and North America. Although international rules restrict such exports, a substantial amount of e-waste from the Global West still ends up in Africa and Asia through illegal trafficking channels, in violation of the Basel Convention, which controls the transboundary movement of hazardous wastes.

One of the most well-known accumulation sites is Agbogbloshie, Ghana. For years, it has received large quantities of discarded electronics from Europe and elsewhere. Informal workers dismantle

and burn cables and devices to recover metals like copper. This causes pollution of soil and water, as well as tremendous health issues for the workers who are exposed to dangerous fumes.

Watch this video to get a clearer sense of the vast scale of the site and its environmental and health impacts. (*https://video.corriere.it/esteri/benvenuti-nell-inferno-dove-finiscono-nostri-vecchi-cellulari-computer/7a226c1e-007e-11ea-90df-c7bf97da0906*)



An e-waste site in Accra, Ghana, where people sort and burn discarded electronics to recover valuable materials, often under hazardous conditions.
Image: Left: The Basel, Rotterdam and Stockholm Conventions/FlickR, CC BY-NC-SA 2.0; right: Fairephone/FlickR, CC BY-NC 2.0

Recycling deficit

Considering that our mobile phones contain more than 50 different raw materials, just imagine how many grams of precious metals are hidden inside them! How many tonnes of materials do we lose if we do not recycle devices properly?

In 2022, only 22.3% of global e-waste was documented as properly collected and recycled in an environmentally sound manner.[8] This figure shows the enormous gap between the amount of e-waste generated worldwide and the amount recycled.

One major e-waste bottleneck arises before devices reach disposal facilities: collection. Instead of entering the recycling stream, a massive amount of electronic waste ends up dumped in unsorted waste or forgotten in people's homes. In EU households alone, an estimated 700 million unused smartphones are kept.[9]

When devices are finally collected, they run into a second barrier: the extreme complexity of tech recycling. Modern smartphones are masterpieces of micro-engineering, designed by glueing and sealing together dozens of different elements, including rare earths, gold, cobalt, and lithium. Separating these pure materials without damaging them or releasing hazardous substances into the environment requires sophisticated and expensive chemical and industrial processes.

What can we do on our part?

Before a device reaches a recycling plant, we must prioritise extending its life cycle through maintenance, repair, refurbishment and reuse. This drastically reduces the demand for new resource extraction and yields far higher environmental benefits than recycling alone.

You can also repurpose your phone, turning it, for example, into a remote control, portable wifi hotspot, e-reader or digital photo frame.[10] Repurposing is beneficial when it prevents the purchase of another device. However, if the phone can still function normally, passing it on to another user may preserve more value.

If you tried to repair your phone but still have to replace it, remember to take it to a specialised WEEE recycling centre and follow your city's disposal rules! Specialised facilities disassemble the phone to recover intact components (cameras, bodies, microphones, connectors) or microchips to be used for repairing other devices. This is called urban mining.[11]

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