# *Global Cobalt Mining and Processing*

# *Environmental and Social Impacts*



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# Mining and the Environment

Unlike other production activities which can be controlled by the design and location of the facility in which they occur, **mining—by its very nature—happens outside in the environment itself, with ore located in places not chosen by humans but rather dictated by the planet's formation processes**.

In 2003, the World Resources Institute conducted an analysis of mines which revealed the following[1]:

- More than one quarter of active mines and exploration sites overlap with or were within a 10-kilometer radius of a strictly protected environmental area.
- Nearly one third of all active mines and exploration sites were located within intact areas of high conservation value.
- Nearly one third of all active mines were located in stressed watersheds.
- Nearly three quarters of active mines and exploration sites were located in areas deemed by conservation organizations to be of high ecological value.

In addition, as many of these mines are in remote areas, infrastructure to transport and further refine the materials offsite create their own set of environmental impacts.

After the mining, the first steps of processing minerals are often done outside, given the large amount of waste material present. This includes grinding and crushing ore, but often can include the addition of chemicals to the ore.

While there are ways of mitigating—but never to eliminate—the environmental impacts of mining, **unfortunately it is likely that mining's sustainability impacts will only get worse over time, not better**. Barring geopolitical and other factors, mining of minerals generally begins with the closer-to-the-surface and higher quality ores, so as time goes on, in order to continue to mine we will unavoidably need to:

- seek out reserves in more protected and fragile ecosystems
- encroach on more indigenous populations, and
- expend more energy and use more chemicals to try to extract more diluted materials from ores

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# Cobalt Chemistry and Ores

- Cobalt has been in use since ancient times as a pigment, for example, as blue glaze on pottery in Egyptian tombs. It wasn't until 1735 that cobalt was isolated as an individual element[2]
- Its name comes from the German word for goblin or evil spirit and the Greek word for mine, because cobalt was sometimes mistaken for what at that time were more valuable minerals[3]
- Cobalt has one naturally-occurring isotope (Co59)[4]; the radioactive isotopes are produced in a lab. **For the remainder of this presentation, all references to cobalt are to the Co59 non-radioactive isotope.**
- Demand for cobalt was very low until the development of cobalt-chromium alloys in the early 1900s.[3] Today, cobalt has the following uses[5]:
    - Cathodes in rechargeable batteries—lithium-ion, Ni-Cd, Ni-metal-hydride
    - Superalloys for turbine engines in jets and terrestrial energy generation
    - Magnet applications—marine propulsion, missile guidance, sensors, and radar
    - Cemented carbides—cutting tools and wear-resistant components
- **While companies like Tesla have stated their intentions to reduce or eliminate cobalt dependency in their EVs[6], cobalt helps improve stability and longevity of batteries at high power levels and is comparatively lightweight and space saving compared to other options available**[7]
- Some potential technology developments are in progress to avoid cobalt use in rechargeable batteries, but none seem to have yet made it to cost-effective viability[8]

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# The "Geological Scandal" of the Democratic Republic of the Congo (DRC)

- Although pure cobalt is not found in nature[9], cobalt is element #33 in terms of crustal abundance[4] It is less common, though, than all other transition metals except scandium[3]
- **Cobalt is typically mined as a by-product of copper and nickel**[2]. It is, however, "more dispersed in the crust than either of those elements, and concentrated mineral deposits are consequently rare."[3]
- **More than 50 percent of cobalt mining is in the Central African Copperbelt** (primarily the DRC, and less than 10% in Zambia).[10,11] The deposits in the Copperbelt are the results of a confluence of unique geological events unlikely to be reproduced elsewhere on earth[11]
- Apparently the Copperbelt has been called "the "geological scandal" because it is so rich in metals, they have almost the entire table of Mendeleev there."[11]
- Overall, one estimate believes the DRC could have $214 trillion in untapped mineral resources.[11]
- In addition, for cobalt, "**The DRC has some of the highest quality reserves globally, with many mines having grades above 3% compared to the global average of 0.6 to 0.8%.**"[11]
- **In 2018, all other countries produced no more than 5% of the total of cobalt mined.**[12] The only (reasonably-sized) mines where cobalt is mined as a primary product are in the Bou Azzer district in Morocco, but which only represented 2% of production in 2017[5] and has only 2-3% of the world's estimated cobalt reserves[13]
- As with most mined metals, initial processing happens close to the mining sites, to begin to concentrate the mineral. This avoids energy- and cost-intensive transportation to downstream refining operations of what is primarily waste material.
- **In the DRC: for example, at one processing center the mineral/ore contains 1.4% to 1.6% of cobalt, and after initial processing cobalt is at 12%.**[14] These elements are then exported (usually to China) for further refining.

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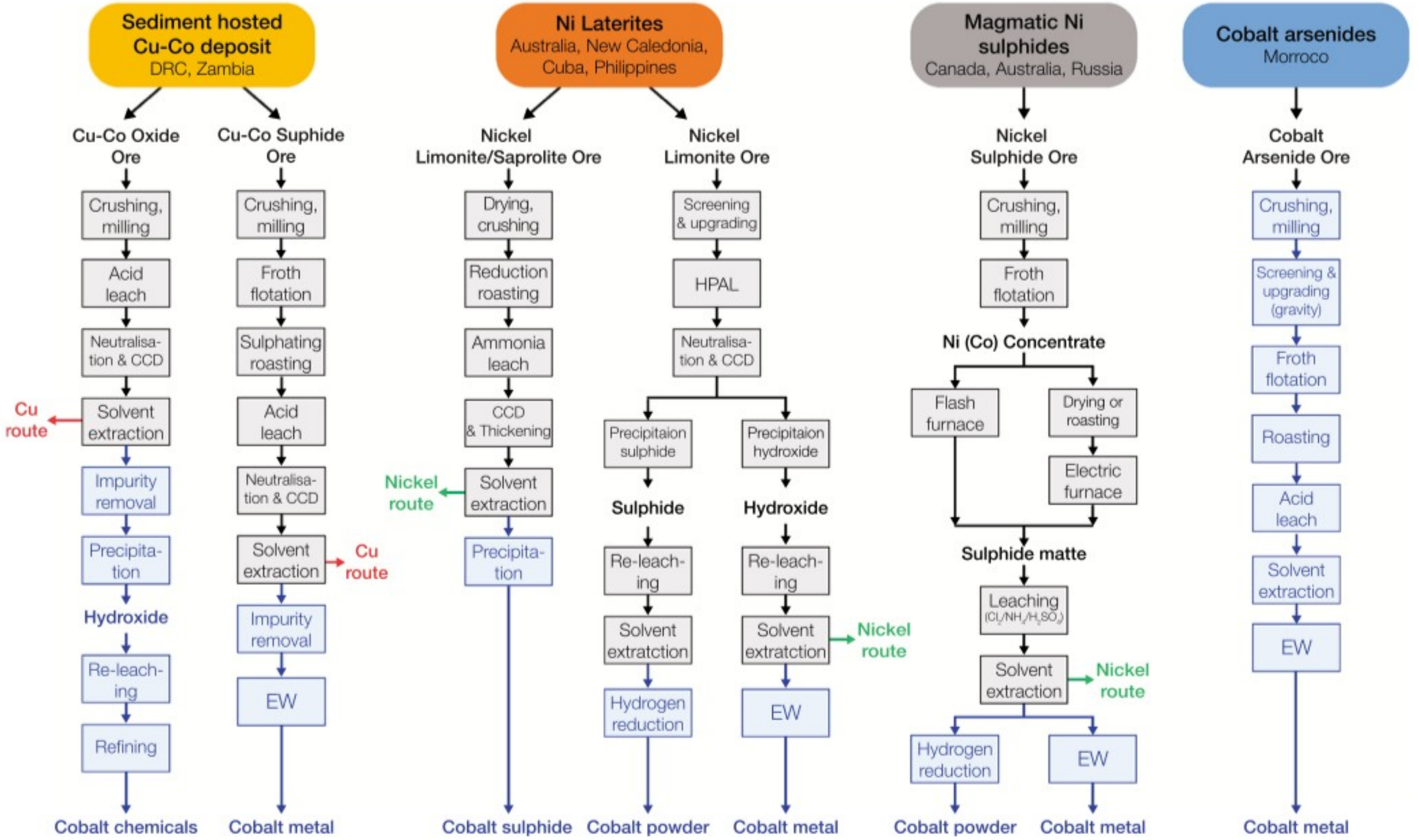


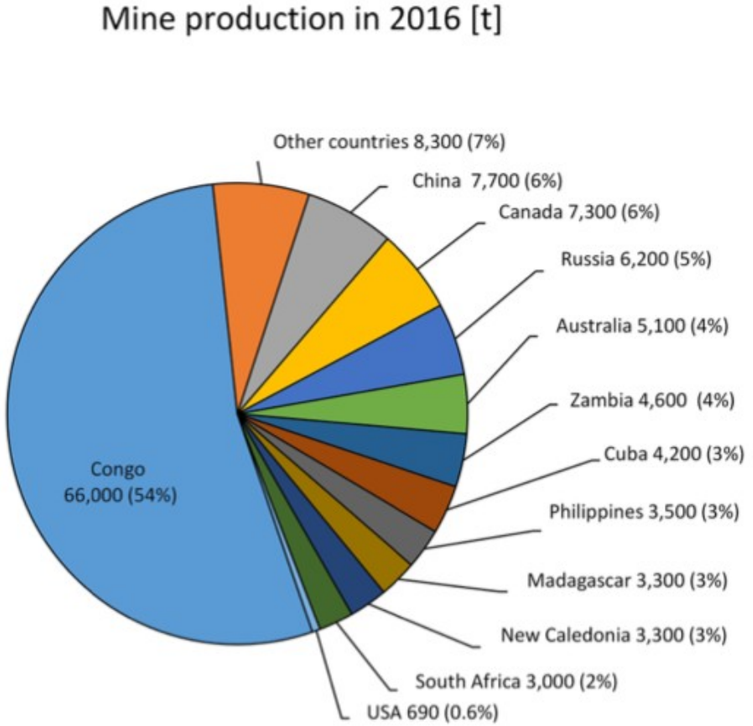

**Fig. 5.** Overview of the main processing routes for cobalt extraction as a function of the deposit and ore type. Alternative processes are presented in parallel. Abbreviations: CCD: Counter-Current Decantation, EW: Electro-Winning, HPAL: High Pressure Acid Leaching.

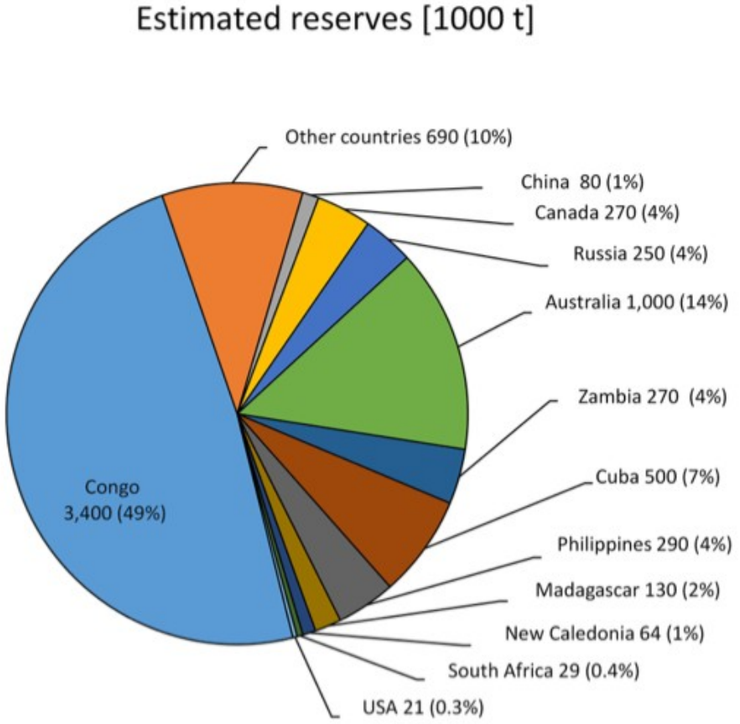
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# Mining the Sea?

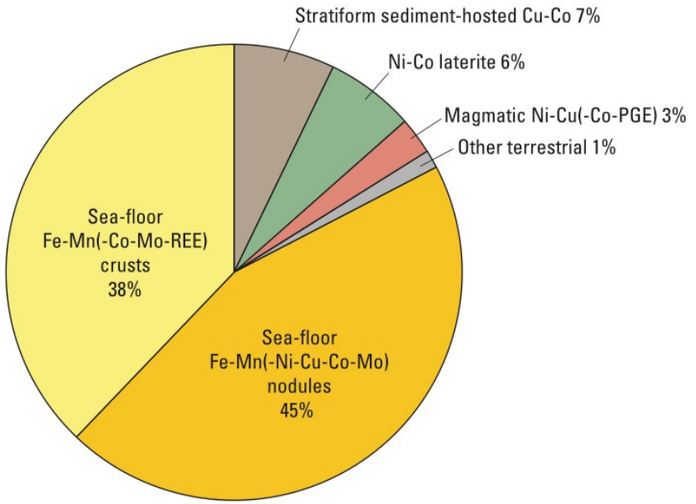
- **Terrestrially, the DRC has ~50% of the world's proven cobalt reserves**[12]
- **However, significant cobalt concentrations are also present in the sea floor**[2], at water depths of as great as 6,000m[9]
- Conservationists, though, are concerned of disrupting the carbon reservoirs held by the deep sea[15]
- Biodiversity is also a concern with sea-floor mining. Per one scientist: "Each time an expedition is launched to collect species, we find that between 70% and 90% of them are new to science. It is not just new species, but whole genera of plants and creatures about which we had previously known nothing."[15]

## Terrestrial Deposits Only




## Terrestrial and Sea-floor Deposits




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# Supply Risks of Cobalt

## Governance risks of cobalt reserve locations

- **Overall, 70% of global cobalt reserves are located in Fragile or Very Fragile States, and 70% of global cobalt reserves are located in States Perceived as Corrupt or Very Corrupt.**[16] As an example, the closure of the Mutanda mine in the DRC in 2019 removed around 20% of the global cobalt supply[17]

## Risks of being a by-product

- Because nearly all cobalt is a by-product of other more abundant minerals, production is driven by the primary metal.[9] As described by one researcher,[18] "**A miner's decision to increase, decrease, or stop mining cobalt-containing copper ore is based on the relationship of the cost of recovering the copper contained in that ore with the copper price that will be received from doing so.**"
- This also means that if the commodity price for the primary mineral is high (Cu or Ni), efforts to recover large amounts of the co-present mineral (Co) may be low, essentially wasting the material that was mined. "**Cobalt recovery in the smelters is relatively low, ranging from 25% to 80% and averaging 50%. This is much lower than the average recoveries for nickel and copper, which are 97% and 95% respectively.**"[4]

## China's control throughout the entire cobalt-to-battery supply chain

- 70% of cobalt is refined in China and as of 2020, China controlled around 74% of global battery cell manufacturing.[8] However, **China also indirectly controls 19–26% of mining production through ownership of mining projects mostly located in the DRC**[10]

# DRC Mining and Labor

- **One cannot tell the story of the mining and processing of cobalt without discussing the social sustainability issues in the DRC.** The labor situation associated with cobalt mining became widely publicized with a 2016 report issued by Amnesty International[19]
- The DRC is one of the poorest countries in the world and it sits in the lowest decile of countries with regard to World Governance Indicators and Environmental Performance Index[20]
- **There is large-scale industrial mining (often abbreviated as LSM, and owned by foreign firms), and artisanal and small-scale mining (abbreviated as ASM, and usually owned by local communities)**[21]
- **LSM mining accounts for 80% of DRC national production, but ASM employs 98% of the workforce.** ASM is low-tech, labor-intensive, and highly dangerous for the miners.[21] Nonetheless, the production of cobalt from ASM sites in the DRC represents the second-largest cobalt-mining sector in the world after LSM production in the DRC[22]
- ASM, per an academic who has interviewed hundreds of people in the DRC[11]:
  - "**Artisanal mining operations are essentially unsafe, ragged holes in the ground, with manual labor, children present, and miners so poor they dig without ladders or tools, some literally by hand**."
  - "The life of an artisanal cobalt miner is particularly dire. They often spend 12 hours in a mine shaft and work through the night, their bodies ache and they always fear landslides or rockslides. Two spoke of nightmares, more than a dozen spoke of brothers, or friends, that have died in a mine, many also spoke of being beaten, chased, or shot at."
  - "A typical ASM worker earns $1 to $3 per day and produces 30 to 50 kilograms of raw ore per day."
- Child Labor
  - In addition, **UNICEF have estimated that around 40,000 children work in the mines of the southern DRC alone.**"[23] "According to Amnesty International, children as young as seven may undertake ancillary tasks like sorting mined ore, before delving into the tunnels themselves from around the age of twelve."[23]
  - **The International Labor Organization (ILO) classifies child mining for cobalt as one of the "worst forms of child labor"**[21]

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# The DRC Situation of ASM is Complex

Organizations such as the World Economic Forum believes that formalization of ASM is necessary.[22] However, programs to address the challenges of ASM may not always result in desired outcomes: "Studies on supply chain initiatives that were established as a result of the conflict minerals campaigns run by international NGOs in the early 2000s in Eastern Congo suggest that **supply chain due diligence initiatives have ambivalent effects on the livelihoods of local communities and that the income of artisanal miners has decreased in some areas.** There were various reasons for these outcomes. For instance,

- artisanal mines had to shut down for long periods of time until certification processes were completed
- authorities rarely issued clear titles for land and mining
- there was a general lack of technical and financial support for artisanal miners
- top-down formalization process and traceability reforms destroyed many of the existing albeit informal local regulations for artisanal mining sites and frequently created tensions among different newly established mining cooperatives."[24]

An academic researcher who has conducted significant interviews with many people in the DRC describes a complex situation no matter what action is taken around ASM: "Because of [the] political economy, it is likely the future of cobalt will remain contested and conflicted. **Someone stands to lose if cobalt mining patterns move in any direction: greater amounts of ASM will involve more children and women, more accidents and landsides, strengthened dependence on mining as a source of income, and deepened devastation local ecosystems. However, fewer amounts will result in unemployment and choke off what little state revenue trickles down to communities already scarred by decades of chronic poverty, corruption, war, and conflict, with many of the most affected people orphans or former refugees.** Put another way, Congolese cobalt operates within a complicated political economy where any attempt to reform livelihoods, manage practices, or govern supply chains will alter power dynamics in ways that may only entrench some degree unsustainability or inequality."[11]

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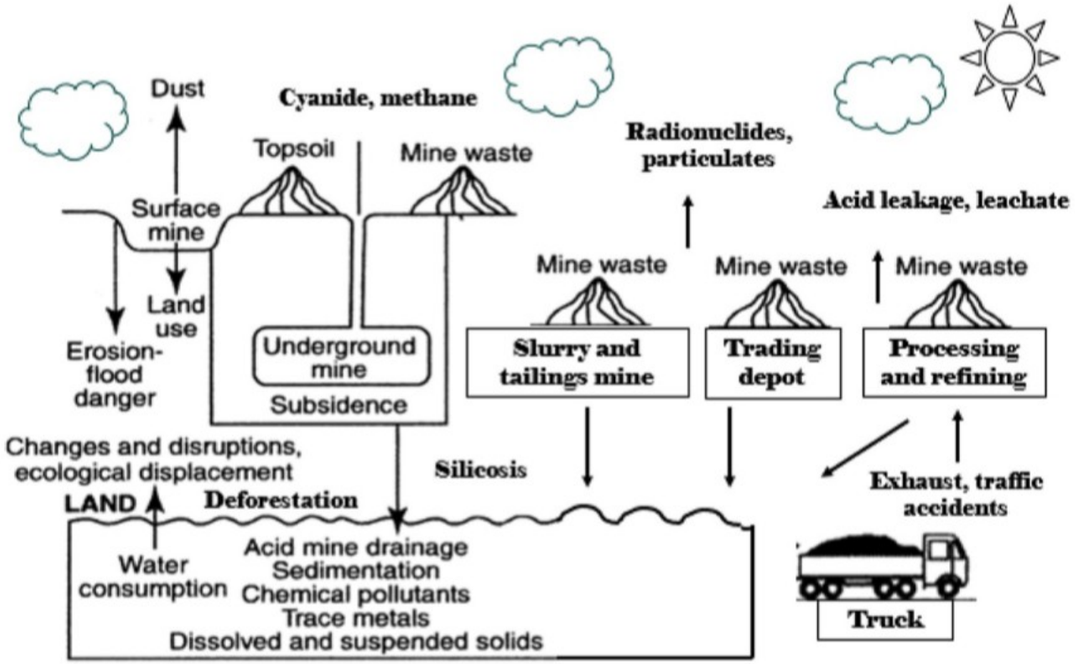
# Banning DRC Cobalt Isn't a Great Option Either

- The reality is none of the choices of actions to take when sourcing cobalt are particularly desirable. For example, there is a **question about whether one should boycott ASM in the DRC**. BMW, for example, decided to source cobalt from Morocco and Australia from 2020 on[22]
- Critics claim boycotting could make the situation worse, noting that, counterintuitively, **banning ASM could actually increase child labor by lowering household incomes**.[11] It also shouldn't be forgotten that "**More than 2 million Congolese rely on ASM for their livelihood and they in turn support about five times as many people**."[22]
- In addition, boycotting cobalt in the DRC by moving to other deposits could increase environmental impacts, depending on the type of deposit and quality of ore: **on average, the cobalt ore sometimes found in Australia is 2-5x more energy intensive to process than the cobalt ore typically found in the DRC**[4]

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# DRC's Lack of Mining Environmental Controls

- As much of the mining and initial processing of cobalt occurs in the DRC, we'll start with the environmental impacts there.
- **Because cobalt is mined a by-product of other minerals, it shares the same sustainability issues up to the point of its separation from the primary mineral during processing (see later slide for details).**
- "**The parts of Zambia and the DRC that host the Central African Copperbelt are considered one of the top ten most polluted areas in the world as a result of the discharge of pollutants from mines and smelters.**"[25]
- **This impact isn't limited to ASM;** industrial mines in the DRC have similarly widespread impacts on the environment[11]
- There aren't really any "accidental" spills in the DRC, **as there don't seem to really be any environmental controls in the first place to fail**. Cobalt ore is washed by miners in bodies of water used for other purposes like drinking. Processors emit chemicals directly into long-dead rivers and out in the air[14]
- ""Mining pollution in Katanga is an undeniable reality," admits member of parliament Davon N'Sa Mputu Elima, who served as environment minister in 2012-14. He says that mining firms put up considerable resistance to a 2009 amendment in the country's environmental code, which imposed stringent new health and safety requirements. **Such protective measures are often not enforced because of what the MP calls "a lack of expertise" among administrative officials responsible for seeing that mining**




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# Human-Health Impacts of Mining and Processing in the DRC



- Researchers document that those merely living close to mines in the DRC had elevated levels of copper and uranium in urine as well as "significantly higher" concentrations of cadmium, copper, cobalt, and uranium in the blood[11]
- **Other research suggests that exposure to toxic pollution is causing birth defects in the children of cobalt and copper miners in the DRC**[27]
- Severe contamination exists in lakes and rivers where cobalt is washed, and where slurry and runoff flows, thus entering food and water supplies[11]
- Amnesty International warned how chronic exposure to cobalt dust leads to a potentially fatal lung disease, called "hard metal lung disease." Inhalation of cobalt particles can also cause "respiratory sensitization, asthma, shortness of breath, and decreased pulmonary function", and sustained skin contact with cobalt can lead to dermatitis.[19]
- One woman who said she carried 50 kg sacks of cobalt ore told Amnesty International that "We all have problems with our lungs, and pain all over our bodies."[19]

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# Cobalt-Related Environmental Issues outside the DRC

Cobalt mining and processing has issues in other countries, not just the DRC[28]:

- "In **Australia**, which is the world's second biggest producer, authorities issued the Whim Creek mine in Pilbara with an environmental protection notice after floods led to levels of cobalt, copper and other metals significantly above water quality guidelines
- In **Cuba** – which has the world's third biggest cobalt reserves – satellite analysis of the huge open-cast nickel and cobalt mine at Moa in Holguín Province appears to show what researchers have described as a "lunar-like landscape" devoid of life over 570 hectares, while they say their research shows pollution plumes have contaminated 8km of coastline and 10km of the Cabañas River
- It is a similar story at **Madagascar**'s biggest foreign investment project – the $8bn (£5.9bn) Ambatovy nickel and cobalt mining complex near Toamasina, which has been blamed for air and water pollution, as well as health problems among the local population
- In **China** inspections by the Ministry of Ecology and Environment in June 2018 temporarily halted production in Jiangxi province, which is the global centre of cobalt refining
- Two years ago, the **Philippines** closed or suspended 17 nickel mines – several of which also produce cobalt – because of environmental concerns"

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# Cobalt's Unavoidable Environmental Risks

Besides the consumption of large amounts of energy to mine and process cobalt ores to convert them into a human-usable form, there are other environmental risks unavoidably related to the chemistry and location of ore deposits:

- **Acid Mine Drainage (AMD)**: Both nickel and copper mining (of which cobalt is mined as a byproduct) creates AMD, where sulfides naturally co-present with these mineral ores are exposed and react with air and water to perpetually generate acid
    - While treatment options are possible to neutralize the acid, there is a long history of mines globally–even in more regulated countries like Canada–of failing to appropriately control AMD, with the disastrous consequence of acid being released into environment
- **Wastes and tailings**: Ore grades are generally in the low-single digits (or even below 1%), thus unavoidably generating a massive amount of waste that must be separated from the desired element. ASM-mined cobalt ore is generally transported as-is to a processor (where there in the DRC there are few-to-none environmental controls on the chemicals emitted from the facility). With LSM-mined cobalt ore, the first step of processing often happens outside in what is called a tailings lake/pond, because there is simply too much undesired waste material for the raw ore to be energy- or cost-efficiently transported elsewhere. In these tailings lakes/ponds, chemicals like sulfuric acid are mixed with the ore to precipitate out more concentrated materials
    - While in optimal situations the bottom barrier of the tailings lake should be made impermeable, natural events like earthquakes and floods (or human engineering failures) regularly break the integrity of these toxic outdoor storage areas. Further refining is usually done indoors in a facility (presenting better options to put in place more controls around chemical liquid and air emissions); depending on the region and company these controls may or may not be present
- **Radioactive and toxic co-present materials**: Cobalt ore is regularly co-present with uranium and arsenic, creating exposure and release risks. Heavy metal toxicity is regular problem for people living near mines and processing plants globally, but in the DRC is especially problematic because of the large amount of dust created, transporting airborne toxins to people in the area. More regulated countries are not free of this issue, though; e.g. in Canada the biggest source of arsenic release into the environment (in this case, into Lake Temiskaming) is from cobalt mining[32]

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# Recycling Cobalt

- **One might argue that recycling in order to simply to conserve what are ultimately limited resources is a valid strategy, regardless of the mining situation.** Apple, for example, announced it will use 100% recycled cobalt in all Apple-designed batteries[29]
- **However, it must be noted that recycling still comes with an environmental—and sometimes negative social, too, depending on how it is performed—impact as well**
- The table from the OECD[30] lists differences in burdens and impacts between primary and secondary (i.e. recycling) production of cobalt; as you might imagine, the impacts of mining are avoided through recycling
- Per the OECD, "significant variability reflects differences in the systems considered and the recycling routes followed (whether to pure metal, to alloys, etc.), but **all of the LCAs identified in the course of this work conclude the same thing, that recycling is more efficient with respect to pollutant burdens than virgin metal production, and in most cases substantially so**."[30]
- A note of caution: a report warns about mined cobalt being labeled as scrap cobalt for recycling, in order to hide cobalt that would not meet international standards[31]

| | Primary production | Secondary production |
|---|---|---|
| Mining | High risks where regulatory structures are either absent or poorly implemented.<br>High risks for illegal and unofficial mining with particular concern over.<br>Substantial reduction in risk possible through effective regulation. | Not applicable. |
| Processing of ores and secondary materials | Significant use of caustic agents and solvents, potentially contaminating air, land and drinking water.<br>Release of arsenic compounds from some cobalt ores.<br>Controllable via regulation.<br>Energy use, generating emissions to air. | Lower burdens relative to primary production in well-regulated environments. |
| Smelting | Emissions to air from power generation and fuel use ($SO_2$, $NO_x$, $PM_{10}$, $CO_2$).<br>Emissions of the pollutants most damaging to health can be closely controlled, both to air and water.<br>Greenhouse gas emissions are controllable partly through efficiency measures and more extensively through the use of low-carbon/carbon-free energy alternatives. | Similar types of impact to those from primary production. However, savings of energy are achievable, though some evidence indicates that these are likely to be modest, less than 10%. This figure may rise as recycling technology advances. |
| Transport | Significant transport distances from DR Congo to main processing sites in China. | Potentially significant given that there will be possibly few centres equipped for reprocessing new types of battery, leading to the movement of secondary materials over significant distances. |
| Overall burdens | Substantial variation in overall burdens through differences in the regulatory framework and enforcement, the type and quality of ore used. and fuels used, especially for power production. | Significant variation possible, again through differences in regulatory framework and enforcement and fuels used for power production. |
| Trends | Increasing burdens as ore grades decline.<br>Reduced burdens through advances in the regulatory environment. | Reduced burdens through advances in the regulatory environment and advances in knowledge and optimisation of recycling technologies for cobalt.<br>Increased burdens where secondary materials are exported to countries that lack efficient processing infrastructure. |

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# Summary

- Mining—by its very nature—happens outside in the environment itself, with ore located in places not chosen by humans but rather dictated by the planet's formation processes. Its sustainability impacts will unavoidably get worse over time as the digging for more minerals continues
- Cobalt's usefulness in rechargeable batteries and other industrial applications have not yet lent it to cost-viable substitution, leading to a significant increase in demand over recent years for applications such as electric vehicles
- Cobalt is almost exclusively a by-product of copper and nickel mining, and as more than 50% mining is in the Central African Copperbelt, primarily the Democratic Republic of the Congo (DRC); this creates significant supply risks
- One cannot tell the story of the mining and processing of cobalt without discussing the challenges of small-scale mining and child labor in the DRC; a complex situation which isn't necessarily best addressed (environmentally or socially) by boycotting cobalt from that region
- The parts of the DRC involved in mining are also considered one of the top ten most polluted areas in the world as a result of the discharge of pollutants from mines and smelters, and other cobalt mines in the world also have had environmental issues, too. Especially in the DRC, this has had significant negative impacts on human health, including children
- While the exact calculations for one company's products would depend on the various processes involved, the academic literature has found overall that cobalt recycling is more efficient with respect to pollutant burdens than virgin metal production, and in most cases substantially so

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# *Thank you*

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