Global Tin Mining and Processing

Environmental and Social Impacts



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History of Tin (Sn)

- The chemical symbol for tin, Sn, comes from the Latin stannum; hence, the name stannite for one of its minerals[1]
- Tin is one of the earliest metals known and used;[2] archaeological evidence shows tin was first mined and processed in Turkey around 3,500 BC
- Tin itself is soft enough to be cut without much force,[3] but because of its hardening effect when alloyed with copper, tin was first used in making bronze[2]
- **Almost without exception, tin is used today in alloys,[1] and in particular, in solders**[3]
- Although it technically is a metallic mineral, **it is rarely used in the elemental form because it decomposes at temperatures below 55 F**[1]
- This allows tin to melt and adhere to many base metals at temperatures considerably below their melting points[3]

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Tin in Electronics

- **Tin's low melting temperature, electrical conductivity, and other favorable characteristics make it an ideal material to permanently link components on printed circuit boards (PCBs)**[4]
- Furthermore, tin is used in the plating and coating process of PCBs as a resist for removing the residual underlying copper[4]
- **As of 2016, nearly half of mined tin was used in soldering alloys for the IT industry**[4]
- Tin has been called the "forgotten foot soldier of the energy transition," as tin is used in just about everything that has a circuit board[5]
- Tin solder used in electronics can be substituted by epoxy resin with added conductive metals (most commonly silver),[6] however, currently, only a few substitutes are used industrially due to cost and inferior performance[6]

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Abundance and Ores

- **Tin is a relatively scarce element with an abundance in the earth's crust of about 2 parts per million (ppm)**, compared with 94 ppm for zinc, 63 ppm for copper, and 12 ppm for lead;[2] this makes tin the 49th most abundant element[1]
- **The only economically important tin mineral is cassiterite (SnO_2), which is a heavy mineral and mechanically and chemically resistant**[7]
- 56% of tin is found in hard rock deposits, which are most commonly industrially mined; 44% is found as alluvial (placer) deposits[4], often mined via ASM
- Compared with commercially viable deposits of copper, lead, zinc, nickel, and bauxite, tin deposits are generally small[1]
- Most tin deposits fall in a grade range of 0.1 to 1% tin[1] but some placer deposits contain as little as 0.015% tin;[3] unfortunately, grades of tin do not seem to correlate with deposit volumes[1]

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Related Materials During Mining

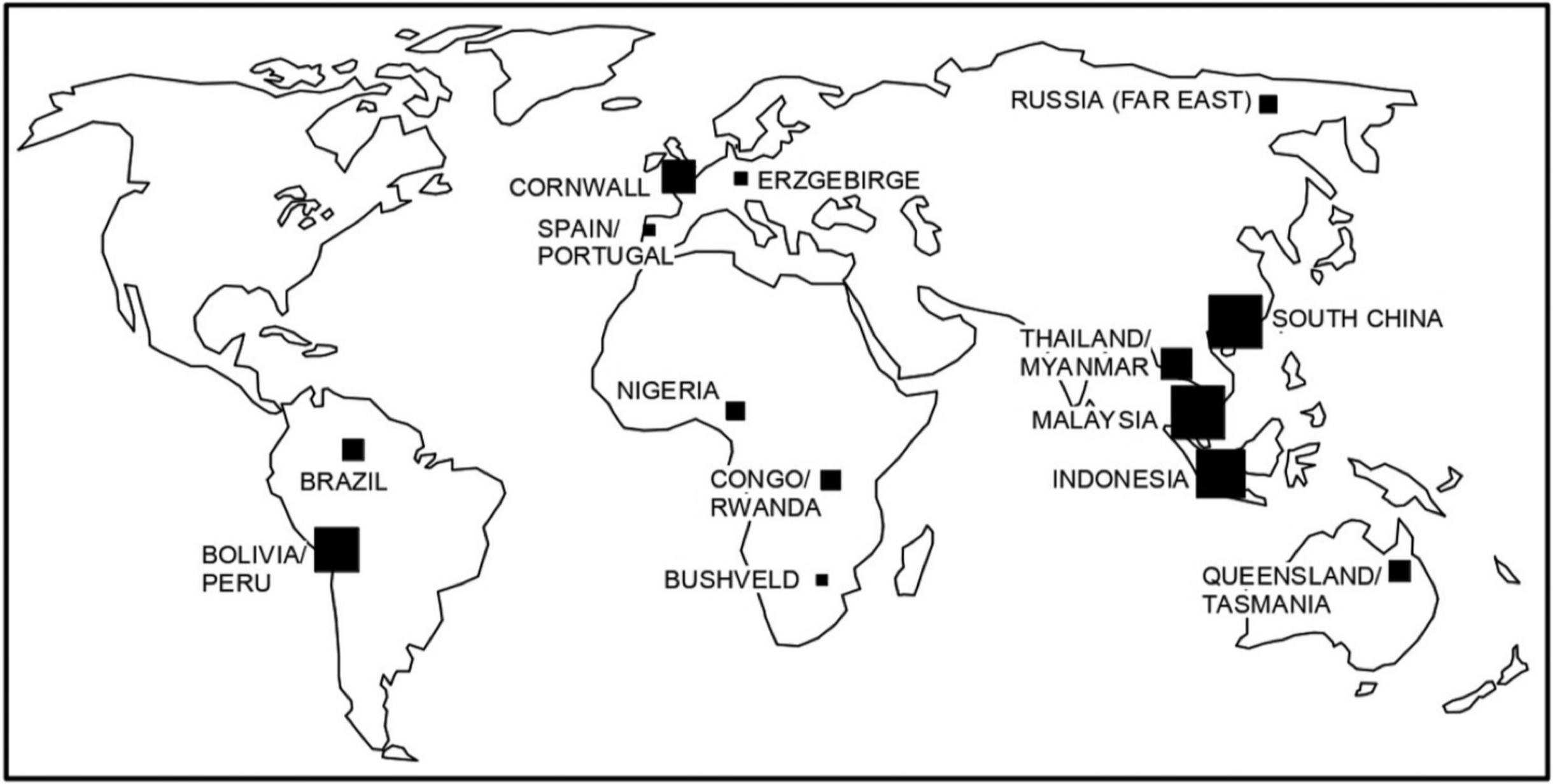
- To date, **more than 99% of tin production has been from tin ore deposits directly, and not mined as a by-product**[7]
- But increasingly, tin is being mined along with tungsten, tantalum, copper, zinc, silver, and lithium. This will depend on relative prices of tin vs other metals[9]
- **Some tin deposits are also co-present with uranium and thorium (radiation), and often are present with sulfide ores (acid mine drainage)**
  - For example, in the Jos Plateau tin deposit in Nigeria mine tailings have radioactivity dose rates approximately 100x those measured in nearby sites[1]
- **Additionally, many of tin's co-present ores contain arsenic.** Unfortunately, this arsenic remains widely distributed in the process of ore-dressing, tailings recovery and smelting[11]

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Miners and Producers

- Only four well-defined regions account for about 85% of the cumulative historic tin mine output. These are[7]:
  - 1. The SE Asian tin belt (Myanmar, Thailand, Malaysia, Indonesia) with a 40–45% share of the total world tin production
  - 2. The South China tin province (20%)
  - 3. The Central Andean tin belt (Bolivia and southernmost Peru) (14%)
  - 4. The Cornwall tin province (7%)
- **These regions also account for about 85% of the current global tin mine production and two thirds of the tin reserves**[7]
- **Tin has significant artisanal and small-scale mining (ASM) - about 40% of the global tin market - mainly in Myanmar, Indonesia, Laos, Vietnam, DR Congo, Rwanda, Nigeria, and partly in Brazil and China**[7]

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Current Production

- **Reliable tin mine production figures are difficult to ascertain,** given the amount of tin from ASM and state producers[8]
- Based on best estimates, the three largest tin mining countries are China, Indonesia, and Myanmar (Burma), accounting for nearly three-quarters of tin production; also the three with perhaps the least reliable data[8]
- **China is the largest producer and consumer of refined tin, with much of its tin production going into electronics**[6]
- Indonesia is the second largest producer of tin globally, with private smelters but most mines owned by the state-run company[9]
- In 2014 Myanmar experienced a 5-year tin production increase of ca. 4900%[8]
- As of 2015, Myanmar's tin still had to be exported for processing.[8] **In 2014, 97% of tin concentrate/ore that China imported was from Myanmar**[6]

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Reserves

- In 2010, it was stated that tin reserves - in contrast to other metals - were very small, with a lifetime of 22 years[12]
- Later, a different 2015 study indicated that the global supply risk of tin was low[6]
- However, **reserves are a function of economically-extractable, known deposits and thus depend on market prices and as well as exploration and processing capacity investment levels**[6]
- Note that margins are a lot lower for copper, nickel, and tin, however, than for precious metals[13]
- **In 2020, the International Tin Association stated that current demand levels could be supported for another 50 years**[9]
- **There is a significant regional difference in reserves.** For example, in Europe, known resources would last over 1,000 years at 2020 mining rates[9]

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World Mine Production and Reserves: Reserves for Australia, China, Malaysia, Peru, and Russia were revised based on company and Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	—	—	—
Australia	8,772	9,700	[7]570,000
Bolivia	19,628	18,000	400,000
Brazil	15,517	18,000	420,000
Burma	[e]36,900	31,000	700,000
China	[e]90,000	95,000	720,000
Congo (Kinshasa)	[e]16,700	20,000	130,000
Indonesia	[e]70,000	74,000	800,000
Laos	[e]1,980	1,900	NA
Malaysia	5,000	5,000	NA
Nigeria	[e]1,600	1,700	NA
Peru	26,995	29,000	130,000
Russia	3,000	2,700	430,000
Rwanda	[e]2,000	2,200	NA
Vietnam	[e]5,400	5,200	11,000
Other countries	1,180	1,100	310,000
World total (rounded)	305,000	310,000	4,600,000

World Resources:[6] Identified resources of tin in the United States, primarily in Alaska, were insignificant compared with those of the rest of the world. World resources, principally in western Africa, southeastern Asia, Australia, Bolivia, Brazil, Indonesia, and Russia, are extensive and, if developed, could sustain recent annual production rates well into the future.

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Criticality

- In the European Union's criticality matrix, tin's low supply risk means it falls just outside of the critical zone[9]
- However, if this supply risk is interpreted differently, or the threshold values change, the result could differ[9]
- **In China and the United States, tin is labelled as critical**[9]

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Geopolitical and Sustainability Risks

- In an assessment of 20 key political, human rights and environmental issues related to the extraction of tin globally, **Myanmar was identified as the second highest risk region for tin mining globally, only just behind the DR Congo**[15]
- Notably, tin production in Myanmar receives extreme risk scores for seven of the 20 risk issues assessed, including for political instability, child labour, corruption, water pollution and deforestation[15]

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Mining Processes[16]

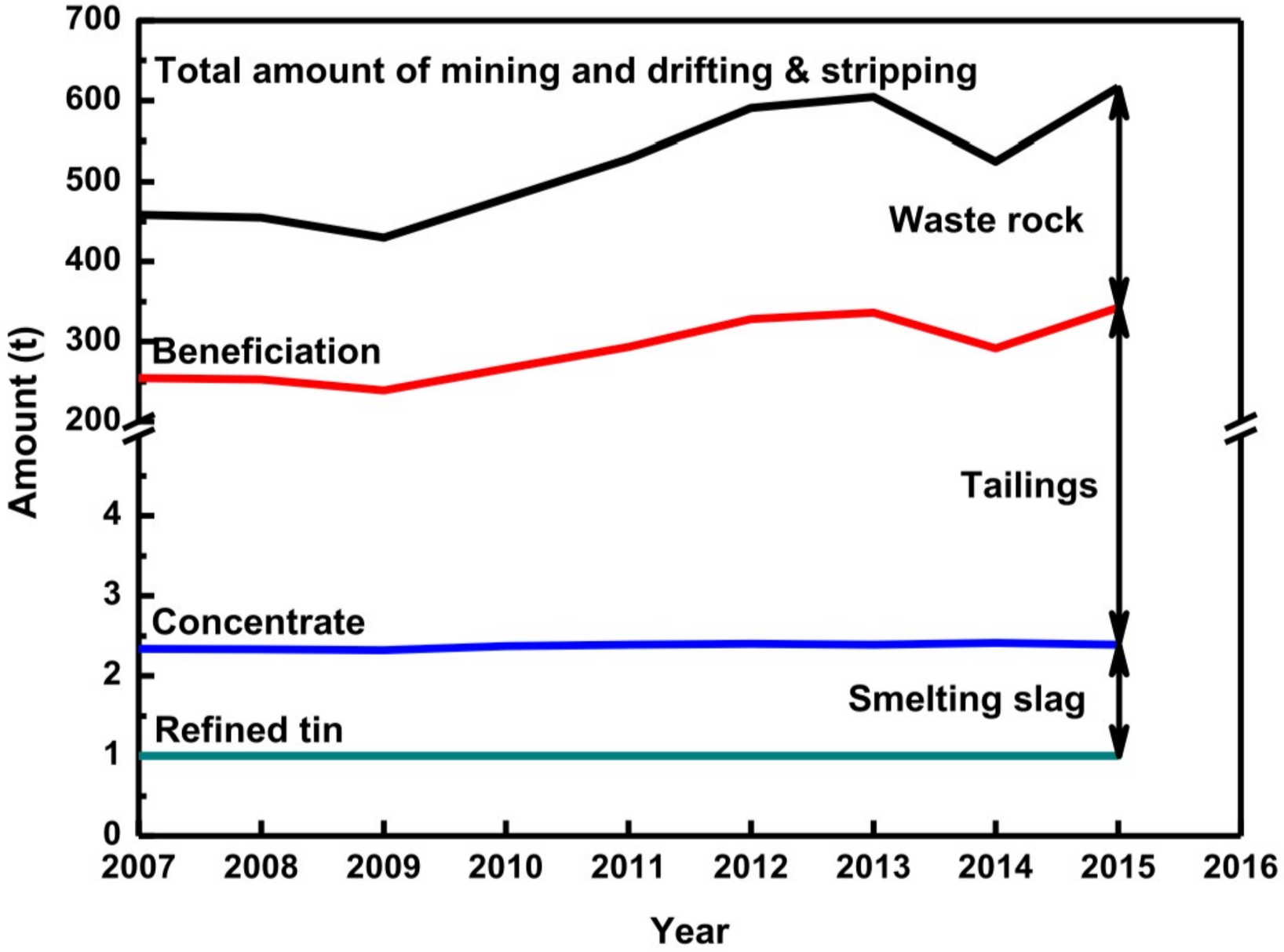
- *Underground mining*: sinking vertical or inclined shafts with horizontal tunnels through hard rock to intersect the mineral veins at right angles where ore can be exposed
- *Open cast (pit) mining*: where ore is removed using mechanical shovels, excavators or manual labour
- *Dredging*: mining alluvial deposits with large floating processing plants (dredges) on the surface of shallow seas or artificial ponds digging out tin-bearing sediments by means of a chain of buckets
- *Gravel pumping*: washing tin-bearing sand from the face of surface mines to a lower pond with a high-powered jet of water, followed by collection from the base of the mine

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Mining and Processing

- **Owing to casserite's high specific gravity, gravity processing is the main method used for initial ore processing**[6]
- However, the high brittleness of cassiterite and its sludging ability leads to large tin losses with this type of processing[17]
- **Only about 50–70% of cassiterite can be recovered, because the fine particles are lost in the gravity tailings**[6]
- **In the past two decades, cassiterite processing has been facing challenges like lower tin-grade, finer grain size, and more complicated mineralogy**[18]

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for Chinese production only

Fig. 6. Assessed amount of mining and drifting & stripping, beneficiation, and smelting for producing 1 ton of refined tin.

Background: Conflict in the DRC

- The humanitarian and human rights situation is dire in the conflict-affected areas[19]
- Human rights violations include arbitrary or unlawful killings, disappearances, torture of civilians, cruel, inhuman and degrading forms of punishments, arbitrary arrests or detentions, recruitment of child soldiers and sexual violence, including mass rapes of children, women and men[19]
- More than 5.5 million persons have lost their lives due to the on-going conflict in the DRC, making the conflict the deadliest conflict since World War II[19]
- **The conflict in Congo is complex and is underpinned by a web of long-standing political tensions, ethnic grievances and disputes over land. But it is also fueled and funded, at least in part, by mineral resources**[20]

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Tin Funding Conflict in the DRC

- **Armed groups gain their revenue from illegal mining, exploitation and taxation of natural resources**[19]
- **They often force the local population to work in the mines, extracting minerals from the ground, or illegally "tax" artisanal miners and mining operations**[19]
- **The revenue raised from the illegal mining operations is used to purchase weapons, fueling the violence and unrest**[19]
- In an article entitled "The richest, riskiest tin min on Earth", the Economist notes about a tin mine in the Congo: "The ore they contain is 4.5% grade. That means that for every 100 tonnes of ore extracted, the firm will be able to sell 3.25 tonnes of tin (not all the tin can be extracted from the rock). Most other mines would be happy to produce 0.7 tonnes."[21]

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Conflict Minerals Regulation

- Estimates of global 3TG production show that, **the DRC is not a major world producer of tin, tungsten, or gold (at 5%, 2%, and <1 %, in 2018)**[22]
- **Nonetheless, the value of illegal mineral trade from the DRC is hundreds of millions of dollars** and a substantial source of finance for armed groups[22]
- **Following a 2012 U.S. regulation (the Dodd-Frank Act), companies have spent billions of dollars scrutinizing whether certain minerals used in their products come from mines controlled by these armed groups**[23]
- The reforms have been extensively studied, and academic research in turn has triggered empirical policy and advocacy researches. Researchers have found different outcomes and interpretations of the effectiveness of the reforms[24]

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Conflict Minerals Regulation (cont.)

- Unfortunately, the US regulations do not require companies to assess the origins of minerals from other conflict zones[23]
- For example, **the Wa State, Myanmar's most powerful ethnic armed group, controls the tin-mining area on the border with China**[25]
- **The European Union passed the Conflict Minerals Regulation in 2017 (requirements starting in 2021), introducing new transparency requirements for importers of tantalum, tin, tungsten and gold from conflict-affected regions (not just the DRC)**[19]

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Human Health

- In Nigeria, the calculated **radiation** dose parameters for the soil samples were all higher than the recommended safety limit[26]
- In China and elsewhere, **heavy metals** including cadmium, lead, copper, and especially arsenic are commonly co-present with tin ores[27]
- Because of the presence of silicon as well, inhalation of **silica dust** along with **arsenic particles** in dust, leads to an increase of lung cancer risk[28]
- In Indonesia, the health and lives of miners are often threatened, due to the lack of, or **poor, health and safety standards**[4], causing the death of ~150 miners every year[33]. Child labor has been reported as well[33]
- Many of the abandoned mining pits fill with water and are ideal breeding grounds for mosquitos, creating health problems, especially **malaria**, for miners and the local population[4]

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Human Health (cont.)

- In Malaysia, based on the results of **water quality** analysis, catchment water did not meet international standards for use as raw water and portable water[29] In addition, **radiation** showed values that exceeded the regulatory limit[30]
- In Russia, the research results indicate that the **toxic wastes** of reprocessing of tin materials accumulated in tailings ponds by both closed and operating mining enterprises constitute a major threat to the environment and to humans of the Far East Federal District[31]
- In Brazil, scientists found that the concentration of **lead in breast milk** were higher on average than those of mothers outside the area, and the highest concentrations in the metal smelter area were above the critical limit set by the WHO[32]

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Environmental Impact: Indonesia Example

- At present, there are very limited studies available on the global environmental impacts of tin[34], but there are many local stories and studies

Mining On Land

- Tin mining began more than 200 years ago[35] and continues today
- Before mining activities took place, shrubs, agricultural land, and forests with diverse vegetation-covered the islands[36]
- Approximately 75% of the land is under mining licenses, although production has expanded nonetheless into both protected and conservation forests[33]
- 64% of the Bangka-Belitung land area is comprised by abandoned pits filled with stagnant water[33]
- Unconventional (ASM) mining is the most significant contributor to land and forest destruction, reaching 30% of Bangka Belitung forest area[37]

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“Tin mining is a lucrative but destructive trade that has scarred the island's landscape, bulldozed its farms and forests, killed off its fish stocks and coral reefs, and dented tourism to its pretty palm-lined beaches. The damage is best seen from the air, as pockets of lush forest huddle amid huge swaths of barren orange earth.”

—Kate Hodal, Journalist
“Death metal: tin mining in Indonesia” *The Guardian*

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Environmental Impact: Indonesia Example (cont.)

Mining Offshore

- Many of the placer deposits located in SE Asia are located offshore[1] and most the offshore deposits are mined by dredging methods[1]
- From a journalist, “Encircling the island are the dredgers and the suction ships and the thousands of illegal pontoons sucking up ore from the seabed like mechanised mosquitoes.”[38]
- Offshore mining activities generate changes the ocean biodiversity and water quality as well as it threatens the province's coral reefs, out of which 50% are already reported to be in a critical condition[33]

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Recycling

- Tin is highly recyclable[13], like other metals. The proportion of scrap used in tin production is estimated at 10-25%[1]
- As tin is also used in alloys, too, so the rate could be higher when considering the reuse rates of brass and bronze (~20%) and solder alloys (30-40%)[4]
- Life cycle data on the recycling of tin is scarce - only in a report from the Bureau of International Recycling was any global data estimated. It found that GWP value for recycled tin is 99% smaller than for virgin tin[13]
- Based on numbers from China, recycling 1 ton of refined tin was found to save ~30% of the energy, not to mention a significant reduction in hazardous waste material[6]
- Waste circuit boards are an obvious source of post-consumer material, given PCBs consume a lot of the virgin tin produced today

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Summary

- Tin has been used since the Bronze Age, and continues to be used today as an alloy, primarily as a solder for electronics
- Tin is relatively scarce, and its only economically viable ore is cassiterite, which due to its chemistry leads to losses of 20-30% during initial processing
- Cassiterite is co-present in many places with heavy metals including arsenic, as well as radioactive uranium and thorium
- Myanmar, China, and Indonesia are the third largest countries mining tin, and the DRC is a tin producer as well
- Both DRC and Myanmar are involved in armed conflicts, and as such are under regulation from the EU and/or the US for tin sourced that funds armed groups
- A wide range of environmental and health impacts of tin mining are present in all places where it is mined, and Indonesia, mining is not only taking place on land, but on the seabed floor
- Tin like other metals is highly recyclable, and recycling could avoid much of the energy, environmental, and social sustainability impacts that virgin mining and processing has

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Thank you

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References (1 of 4)

[1] Kamilli, R. J., Kimball, B. E., & Carlin Jr., J. F. (2017). Tin. In Tin (USGS Numbered Series No. 1802-S; Professional Paper, Vols. 1802-S, p. 68). U.S. Geological Survey. https://doi.org/10.3133/pp1802S

[2] USGS. (2017). Tin Statistics and Information. https://www.usgs.gov/centers/national-minerals-information-center/tin-statistics-and-information

[3] Mills, R. (2021, February 17). Tin: An upcoming "green" metal. Kitco News. https://www.kitco.com/commentaries/2021-02-16/As-a-general-rule-the-most-successful-man-in-life-is-the-man-who-has-the-best-information.html

[4] Stahr, C., Rüttinger, L., & Lorenzen, A. (2016). Fair soldering tin: Recycling, supply chain interventions, or material alternatives? 2016 Electronics Goes Green 2016+ (EGG), 1–5. https://doi.org/10.1109/EGG.2016.7829834

[5] Morse, I. (2021, August 19). Miners get tin trouble [Substack newsletter]. Green Rocks. https://greenrocks.substack.com/p/tin-mining-indonesia-energy-transition-climate

[6] Yang, C., Tan, Q., Zeng, X., Zhang, Y., Wang, Z., & Li, J. (2018). Measuring the sustainability of tin in China. Science of The Total Environment, 635, 1351–1359. https://doi.org/10.1016/j.scitotenv.2018.04.073

[7] Lehmann, B. (2021). Formation of tin ore deposits: A reassessment. Lithos, 402–403, 105756. https://doi.org/10.1016/j.lithos.2020.105756

[8] Gardiner, N. J., Sykes, J. P., Trench, A., & Robb, L. J. (2015). Tin mining in Myanmar: Production and potential. Resources Policy, 46, 219–233. https://doi.org/10.1016/j.resourpol.2015.10.002

[9] International Tin Association. (2020). Global Resources and Reserves. https://www.internationaltin.org/wp-content/uploads/2020/02/Global-Resources-Reserves-2020-Update.pdf

[10] Zhang, S., Zhang, R., Lu, J., Ma, D., Ding, T., Gao, S., & Zhang, Q. (2019). Neoproterozoic tin mineralization in South China: Geology and cassiterite U–Pb age of the Baotan tin deposit in northern Guangxi. Mineralium Deposita, 54(8), 1125–1142. https://doi.org/10.1007/s00126-019-00862-y

[11] Pu, Z., Han, J., Li, Y., Dai, Y., Yang, B., & Wang, A. (2018). Removal of Arsenic from Crude Tin by Vacuum Distillation. Materials Transactions, 59(2), 311–315. https://doi.org/10.2320/matertrans.M2017303

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References (2 of 4)

[12] Izard, C. F., & Müller, D. B. (2010). Tracking the devil's metal: Historical global and contemporary U.S. tin cycles. Resources, Conservation and Recycling, 54(12), 1436–1441. https://doi.org/10.1016/j.resconrec.2010.06.008

[13] Proske, M., Clemm, C., & Richter, N. (2016). Life cycle assessment of the Fairphone 2. Fraunhofer IZM. https://www.fairphone.com/wp-content/uploads/2016/11/Fairphone_2_LCA_Final_20161122.pdf

[14] USGS. (2023). Tin Mineral Commodity Summary 2023. https://pubs.er.usgs.gov/publication/mcs2023

[15] Verisk Maplecroft. (2016). Myanmar's Tainted Tin Is Entering Company Supply Chains. Verisk Maplecroft. https://www.maplecroft.com/insights/analysis/myanmars-tainted-tin-is-entering-company-supply-chains/

[16] International Tin Association. (2023). Sustainable Production. International Tin Association. https://www.internationaltin.org/sustainable-production/

[17] Matveeva, T., Getman, V., & Karkeshkina, A. Y. (2021). Flotation Extraction of Tin from Tailings of Sulfide-tin Ore Dressing Using Thermomorphic Polymer. Eurasian Min, 2, 46–49. https://doi.org/10.17580/em.2021.02.10

[18] Li, H., Yang, C., Tian, Z., Wu, C., & Qin, W. (2023). Cassiterite beneficiation in China: A mini-review. Journal of Central South University, 30(1), 1–19. https://doi.org/10.1007/s11771-023-5245-4

[19] Härkönen, E. (2018). Conflict Minerals in the Corporate Supply Chain: Is Transparency the Solution to Human Rights Violations in the Tantalum, Tin, Tungsten and Gold Supply Chains? European Business Law Review, 29(5). https://kluwerlawonline.com/api/Product/CitationPDFURL?file=Journals\EULR\EULR2018027.pdf

[20] Global Witness. (2017). Section 1502 of the US Dodd Frank Act | Global Witness. Global Witness. https:///en/campaigns/conflict-minerals/dodd-frank-act-section-1502/

[21] The Economist. (2016). The richest, riskiest tin mine on Earth. The Economist. https://www.economist.com/middle-east-and-africa/2016/08/25/the-richest-riskiest-tin-mine-on-earth

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References (3 of 4)

[22] Young, S. B. (2018). Responsible sourcing of metals: Certification approaches for conflict minerals and conflict-free metals. The International Journal of Life Cycle Assessment, 23(7), 1429–1447. https://doi.org/10.1007/s11367-015-0932-5

[23] Lee, Y., & Schectman, J. (2016, November 28). For Apple and others, tin supply chain has ties to rebel-held Myanmar mine. Reuters. https://www.reuters.com/article/us-myanmar-tin-insight-idUSKBN13N1VV

[24] Iguma Wakenge, C., Bashwira Nyenyezi, M.-R., Bergh, S. I., & Cuvelier, J. (2021). From 'conflict minerals' to peace? Reviewing mining reforms, gender, and state performance in eastern Democratic Republic of Congo. The Extractive Industries and Society, 8(2), 100894. https://doi.org/10.1016/j.exis.2021.100894

[25] Home, A. (2023, April 18). Tin spooked by threat of supply disruption in Myanmar. Reuters. https://www.reuters.com/markets/europe/tin-spooked-by-threat-supply-disruption-myanmar-2023-04-17/

[26] Atipo, M., Olarinoye, O., & Awojoyogbe, B. (2020). Comparative analysis of NORM concentration in mineral soils and tailings from a tin-mine in Nigeria. Environmental Earth Sciences, 79(16), 394. https://doi.org/10.1007/s12665-020-09136-7

[27] Liu, Y., Wang, S., Niu, X., Yin, M., He, Z., Hou, J., Zhou, T., Wang, W., & Luo, Y. (2022). Vertical distribution and health risk assessment of heavy metals in soils around tin ore areas in Yunnan, China. International Journal of Environmental Analytical Chemistry, 0(0), 1–14. https://doi.org/10.1080/03067319.2022.2128794

[28] Chen, W., Yang, J., Chen, J., & Bruch, J. (2006). Exposures to silica mixed dust and cohort mortality study in tin mines: Exposure-response analysis and risk assessment of lung cancer. American Journal of Industrial Medicine, 49(2), 67–76. https://doi.org/10.1002/ajim.20248

[29] Ashraf, M. A., Maah, M. J., & Yusoff, I. (2012). Morphology, Geology and Water Quality Assessment of Former Tin Mining Catchment. The Scientific World Journal, 2012, e369206. https://doi.org/10.1100/2012/369206

[30] Rahmat, M. A., Ismail, A. F., Aziman, E. S., Rodzi, N. D., Mohamed, F., & Abdul Rahman, I. (2022). The impact of unregulated industrial tin-tailing processing in Malaysia: Past, present and way forward. Resources Policy, 78, 102864. https://doi.org/10.1016/j.resourpol.2022.102864

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References (4 of 4)

[31] Krupskaya, L. T., Zvereva, V. P., & Bubnova, M. B. (2019). Wastes from the processing of tin ore as a potential source of pollution of ecosystems and a reduction in the risk of environmental disasters in the Primorsky krai. IOP Conference Series: Earth and Environmental Science, 274(1), 012147. https://doi.org/10.1088/1755-1315/274/1/012147

[32] Marques, R. C., Moreira, M. de F. R., Bernardi, J. V. E., & Dórea, J. G. (2013). Breast Milk Lead Concentrations of Mothers Living Near Tin Smelters. Bulletin of Environmental Contamination and Toxicology, 91(5), 549–554. https://doi.org/10.1007/s00128-013-1093-5

[33] EJOLT. (2019). Tin Mining Conflicts in Bangka-Belitung, Indonesia | EJAtlas. Environmental Justice Atlas. https://ejatlas.org/conflict/bangka-belitung-mining

[34] International Tin Association. (2019). Lifecycle Assessment of tin production—International Tin Association. https://www.internationaltin.org/reports/lifecycle-assessment-of-tin-production/

[35] Liliani, R., Retnaningdyah, C., & Arisoesilaningsih, E. (2019). Water Quality Evaluation of Post-Tin Mining Ponds Tourism in Bangka Island Using Diatom as Bioindicator. Journal of Indonesian Tourism and Development Studies, 7(1), Article 1. https://doi.org/10.21776/ub.jitode.2019.07.01.06

[36] Sukarman, S., Gani, R. A., & Asmarhansyah, A. (2020). Tin mining process and its effects on soils in Bangka Belitung Islands Province, Indonesia. SAINS TANAH - Journal of Soil Science and Agroclimatology, 17(2), Article 2. https://doi.org/10.20961/stjssa.v17i2.37606

[37] Haryono, F. (2022). Tin Mining Licensing in the Era of Local Government Reform. International Journal of Multicultural and Multireligious Understanding, 9(2), Article 2. https://doi.org/10.18415/ijmmu.v9i2.3355

[38] Hodal, K. (2012, November 23). Death metal: Tin mining in Indonesia. The Guardian. https://www.theguardian.com/environment/2012/nov/23/tin-mining-indonesia-bangka

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