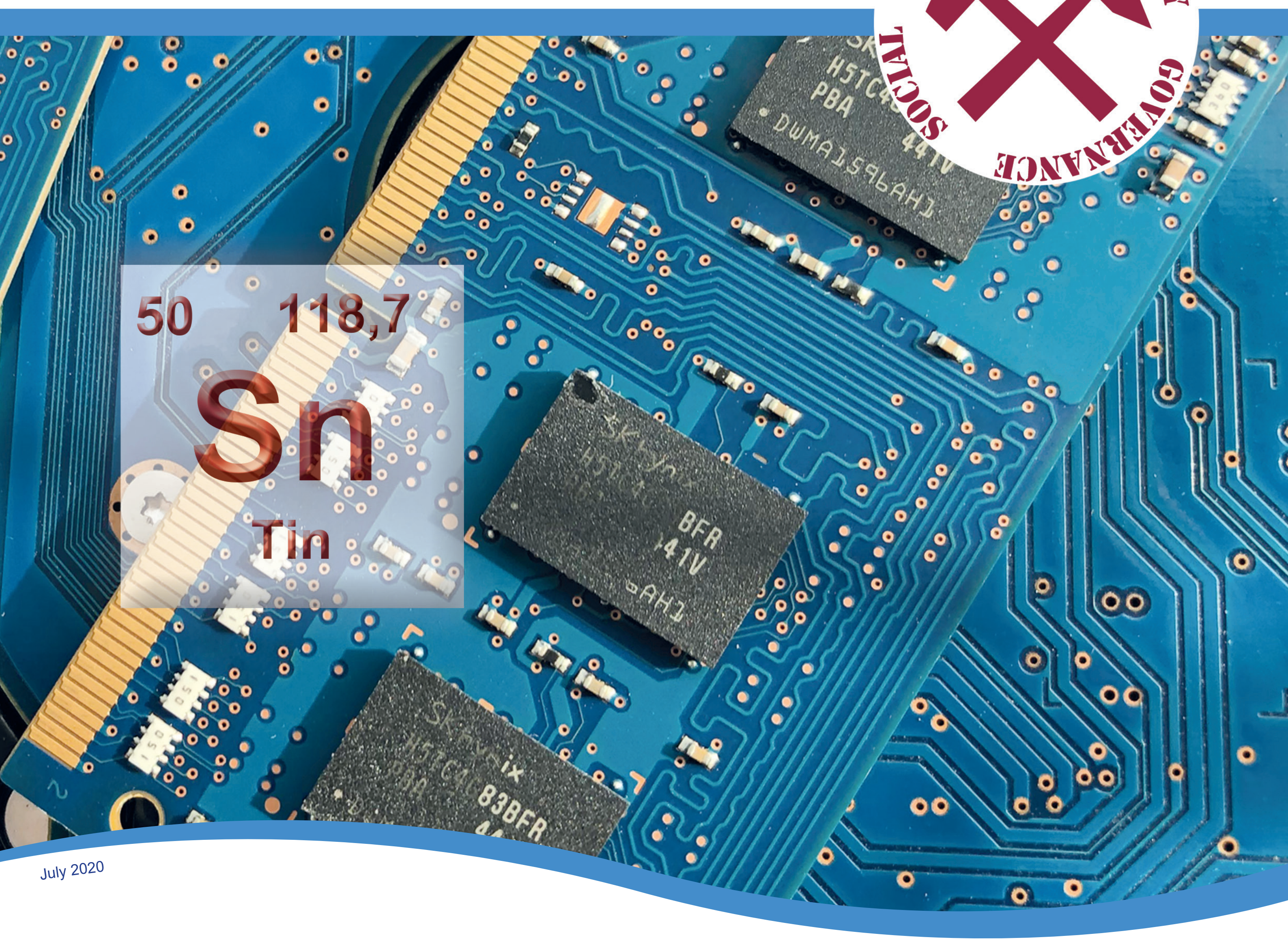
Bundesanstalt für
Geowissenschaften
und Rohstoffe

Tin

Sustainability Information



July 2020

AT A GLANCE

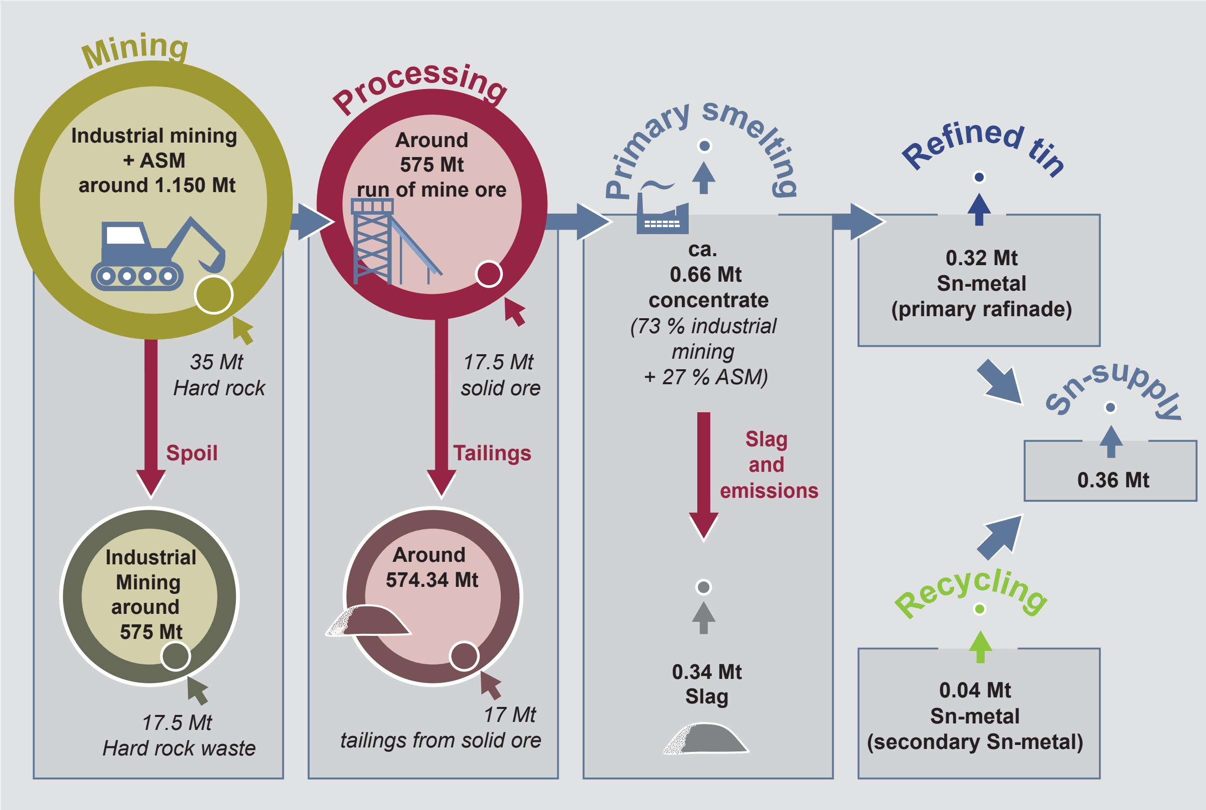


***Abb. 1:** Mass flows in tin production and principal effects on the environment, data for 2017, ASM = artisinal and small-scale mining. Sources: see Sections 4 and 5.*

- The main tin producing countries – China (32 % of global production in 2018 amounting to 305,000 tonnes), Indonesia (25 %), Myanmar (15 %), Bolivia (6 %), Peru (5 %), and Brazil (5 %) – with the exception of China, are not the main tin consumer countries. These are China (45 % of global consumption), USA (9 %), Japan (8 %) and Germany (6 %).
- Mining can impair or negatively affect valuable natural or cultural assets. This is most obviously the case in Indonesia, where large areas have been damaged by gravel pump mining on land and by offshore extraction from the seabed.
- At around 27 %, artisanal and small-scale mining (ASM) has a high share in global tin production. This makes the sector particularly relevant for economic and social development, for example on the Indonesian tin islands Bangka and Belitung, in Central Africa or in Bolivia. On the other hand, this sector must be regarded especially critically due to poor working conditions, uncontrolled mining and lack of renaturation.
- In the east of the Democratic Republic of the Congo, armed groups have also financed themselves through mining and trading tin ore. As one of the so-called „conflict minerals“, therefore, tin falls under the relevant EU regulation, according to which EU importers must comply with appropriate due diligence obligations in their supply chains.

CONTENT

1 TIN´S RELEVANCE

Tin (Sn) is a silvery-white metal that has a very low melting point (231.9 °C) for a metal. One principal use is in solder. Because it forms a thin oxide layer on its surface, tin is chemically relatively inert and is therefore also used for tinning food-safe preserves (tin plating) and in medicine. It is also used in producing alloys, e.g. for bronzes and bearing metals. Tin is increasingly used in the production of chemicals (PVC stabiliser), in manufacturing float glass and in electronics. Relatively new applications have been found as a nanofilm coating in manufacturing solar cells due to the optical-electrical properties of indium tin oxide (ITO), as well as in batteries and as a fuel additive (Fig. 2) [1].

For environmental reasons, the demand for tin is stimulated by the increasing, legally required substitution of lead and antimony by tin and other alloy constituents in soft solders not used in safety-relevant functions.

Tin and inorganic tin compounds are generally considered non-toxic and therefore environmentally friendly. However, organic tin compounds can be toxic. Health risks must be taken into account when using tin compounds, especially in plant protection products. However, there is no evidence of any carcinogenic effects from inorganic and organic tin compounds.

However, in many countries, guidelines limiting the amount of tin in canned food remain in force. Tinned food cans should also be coated. Tin salts should not be used as a food additive.

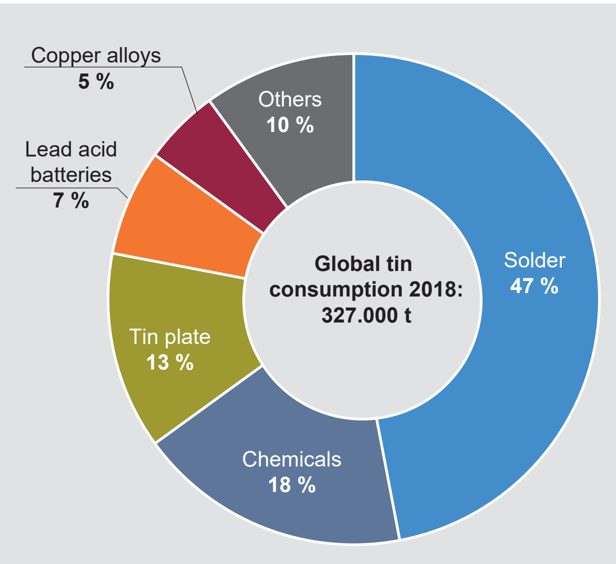


***Fig. 2:** Primary use of tin 2018, modified after [1].*

2 FROM DEPOSIT TO METAL

Tin metal is extracted from tin ores in hard rock and from tin placer in unconsolidated sediments. After extraction, the tin ore is enriched to a concentrate through processing. These concentrates are melted in tin smelters in a multi-stage process, whereby the main mineral cassiterite (tin dioxide) is reduced to metallic tin. Because the tin content after smelting is still too low for many applications, further refining must take place to arrive at a tin product with at least 99% tin content.

2.1 Geologie

Tin is a relatively rare element and is about 50th in the abundance of elements in the earth‘s crust. The average content of tin in the earth‘s crust must be enhanced by a factor of at least 1.000 for economic mining from hard rock and by a factor of at least 50 for tin placer.

Primary tin deposits (hard rock) include greisen, hydrothermal vein and, less frequently, also skarn and volcanic-exhalative deposits (VHMS - volcanic-hosted massive sulphides). The greisen deposits and the hydrothermal veins are late crystallisation products of magmas or of the late phase of hydrothermal events. Because the economically most important tin mineral cassiterite (SnO_2), also known as tin-stone, is a very stable, heavy mineral, a large part of tin production (45 %) comes from secondary placer deposits. They are the result of hard rock weathering followed by the transport and subsequent deposition of cassiterite in sedimentary layers. In some primary deposits, the sulphide mineral stannite is also important for tin production. In primary tin deposits, the mineral is often found in assemblages with arsenic, tungsten, bismuth, silver, zinc, copper and lithium. The economically most important placer deposits are located in Indonesia, Malaysia, Thailand and Brazil, the most important hard rock deposits in Peru, China, Myanmar, the Democratic Republic of the Congo (DR Congo), Australia and Bolivia (Fig. 3).

The three most important tin mining countries are currently China, Indonesia and Myanmar, which together account for around 72 % of the total production (2018) of 305,000 t of tin. 16 % of global mining production came from South America and 6 % from Africa. European production is approx. 0.5 % [3].

The two types of ore, hard rock and placer, usually demand different mining and processing techniques. Hard rock ores are extracted using conventional drilling and blasting operations. Depending on the type and depth of the deposit, the tin ore is mined in open-pit mines, for example in the porphyry type of deposit, which outcrops at the surface, or extracted using underground mining methods, for example from lode ore deposits.

The average size of a tin mining company can be classified as small to medium-sized compared to the extraction of other metal commodities (e.g. copper). After the ore has been extracted from the hard rock, it is usually gently crushed in order to loosen the relatively brittle tin-stone, but not to crush it excessively, because this would make subsequent enrichment more difficult. Density sorting processes (sluice boxes, jig concentrators, blanket tables, shaking tables) are used to pre-concentrate coarse-grained tin-stone in the ore. The flotation process or magnetic sorting is often used to further increase the tin content in the pre-concentrates (Fig. 4) to produce saleable concentrates or to extract and separate by-products. Processing using these comparatively simple mechanical methods is also one of the reasons why a significant proportion of global tin production comes from small-scale mining. Complex tin ores, on the other hand, are characteristic of porphyry deposits, which are almost always extracted in open-pit mining and include numerous by-products. Processing these ores is much more complicated because different tin products and metal concentrates are produced (Fig. 5).

Tin placers are usually prepared in two steps. First, a heavy mineral concentrate is produced using a density sorting process. The heavy minerals are then separated by exploiting the different physical mineral properties, allowing pure mineral concentrates to be produced consisting of tin-stone, monazite and zircon [5].

2.2 Processing

The process for producing crude tin from concentrates depends primarily on whether:

- clean, highly enriched concentrates,
- poor concentrates, but essentially only contaminated by slag forming components or
- complex ore concentrates containing at least one other valuable metal (e.g. tungsten, niobium, tantalum) are involved.

Some of the flotation concentrates from processing must be cleaned before smelting. Oxidative roasting of the concentrate can remove sulphur and arsenic, and iron minerals can be separated from the roasted sinter

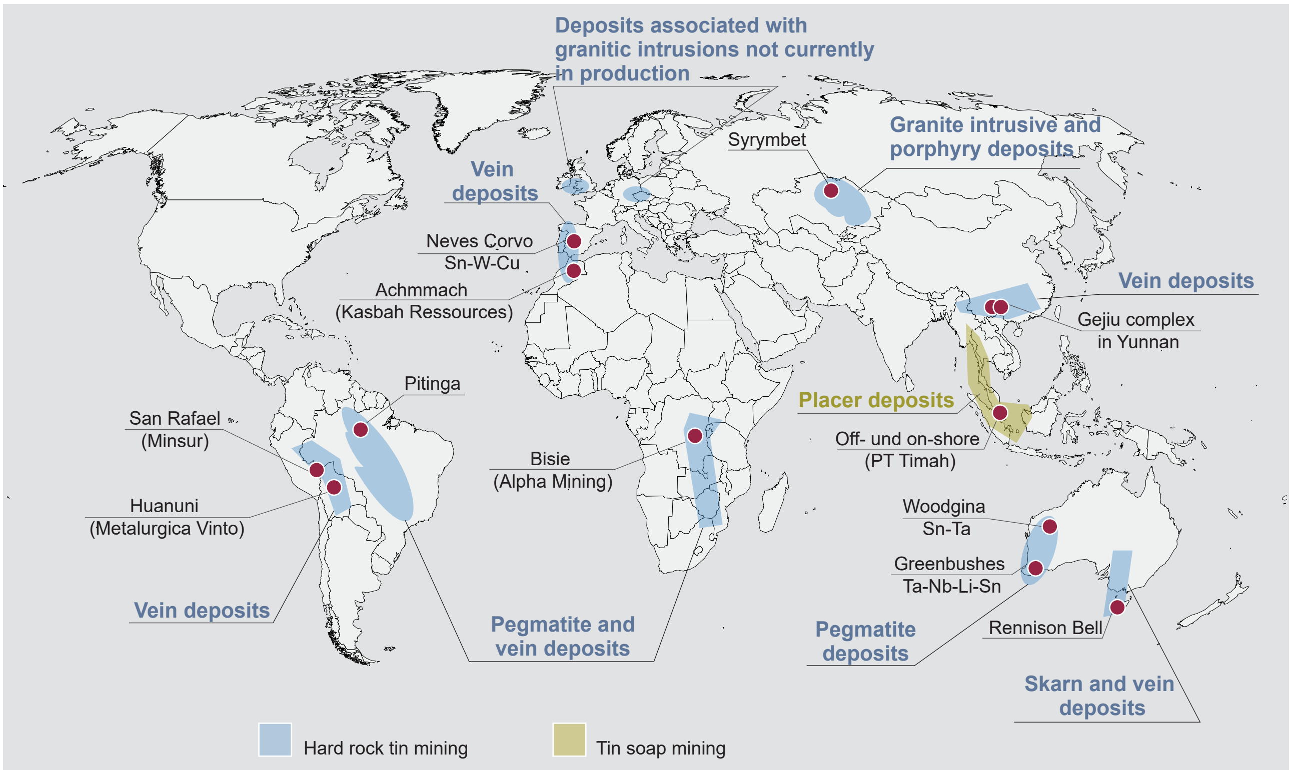


Fig. 3: The 10 largest tin producers and locations of the tin provinces and districts, modified after [2]

by subsequent magnetic separation. Soluble impurities can also be removed by acid leaching.

The tin-rich concentrates are usually smelted in two stages after roasting (Fig. 6). In the first smelting stage, crude tin and primary slag are produced. The primary slag is separated in the 2nd smelting stage into a low-tin slag and a tin-rich intermediate product (hardened tin rich slag), which is returned to the 1st smelting stage. The liquid crude tin is either refined pyrometallurgically by removing the constituents such as copper, iron or arsenic, or alternatively the crude tin is first poured into anode form and then refined electrolytically. Typical smelter products are tin ingots with different levels of purity (98 % – 99.95 % Sn) [4].

A newer smelting process for low-tin concentrates avoids the usual multi-stage roasting, smelting and blasting operations by using a furnace with a smelting cyclone and top-blown lances for reducing gas, in which crude tin and low-tin slag are continuously produced.

Secondary raw materials such as tin-containing flue dust, ashes, residues and slag are melted down in electric furnaces or rotary converters (TBRC process) and reduced to crude tin. As a further option for obtaining tin from complex ores or secondary raw materials, the tin is volatilised as tin sulphide by adding sulphur (fumer) and enriched in the flue dust, which is then fused and reduced to form crude tin.

Total refined tin production in 2018 was 346,000 t. The most important producer countries are China at 48 %, Indonesia at 21 % and Malaysia at 7 % [3].

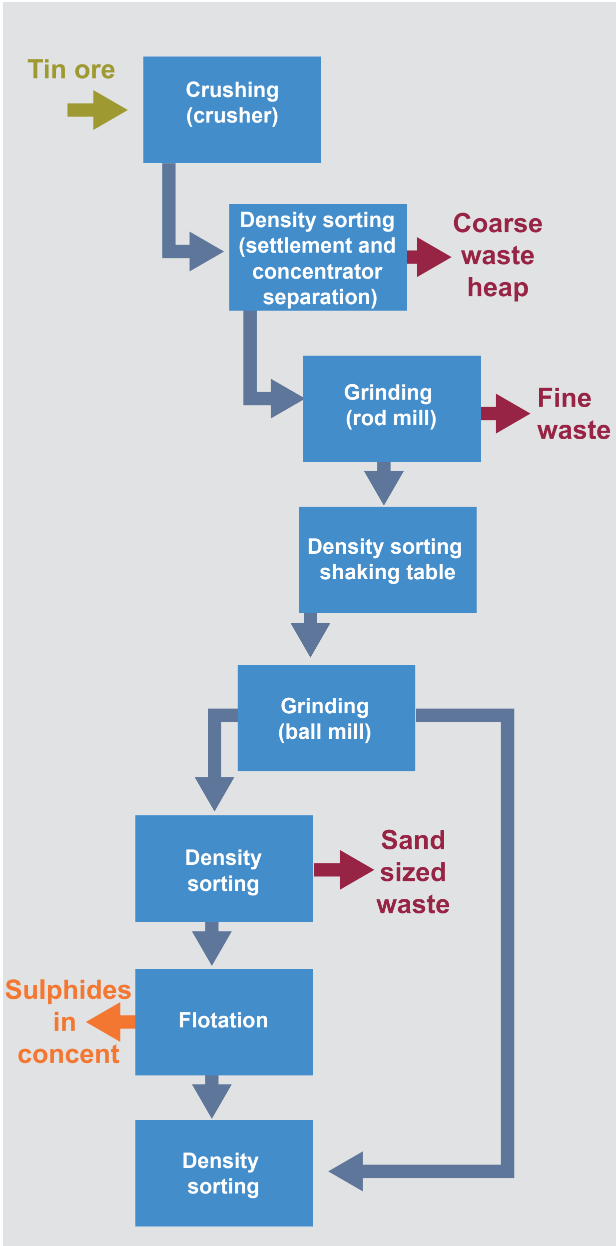


Fig. 4: *Treatment of tin ores from vein deposits.*

3 RECYCLING

Due to the high price it commands, tin is a sought-after recycling metal. However, the cost of recycling varies depending on the parent material.

When recycling tin plate, the tin can only be recovered if the scrap tin plate is free of aluminium. The tin is removed electrolytically in a hot sodium hydroxide solution. Due to the increasingly thin tin coatings on tin plate, it is exceedingly difficult to operate detinning plant economically today. The collected tin plate is therefore often used directly to produce special steels containing tin and the tin is not removed at all [5].

The tin contained in alloys is predominantly recycled, whereas tin solders from the electrical and electronics industry are only recycled to a relatively small extent. Barely any tin in chemical products is recycled because the end use is almost always dissipative. However, large volumes of unneeded tin-containing chemicals are also recycled. The reuse rate of tin-containing primary scrap and alloys is especially high. The end-of-life (EOL) recycling rate for tin is over 50 % on average for all applications. The recycling input rate (RIR) of tin, including refined and unrefined commercial products, was calculated at 30.7 % in 2016 [6].

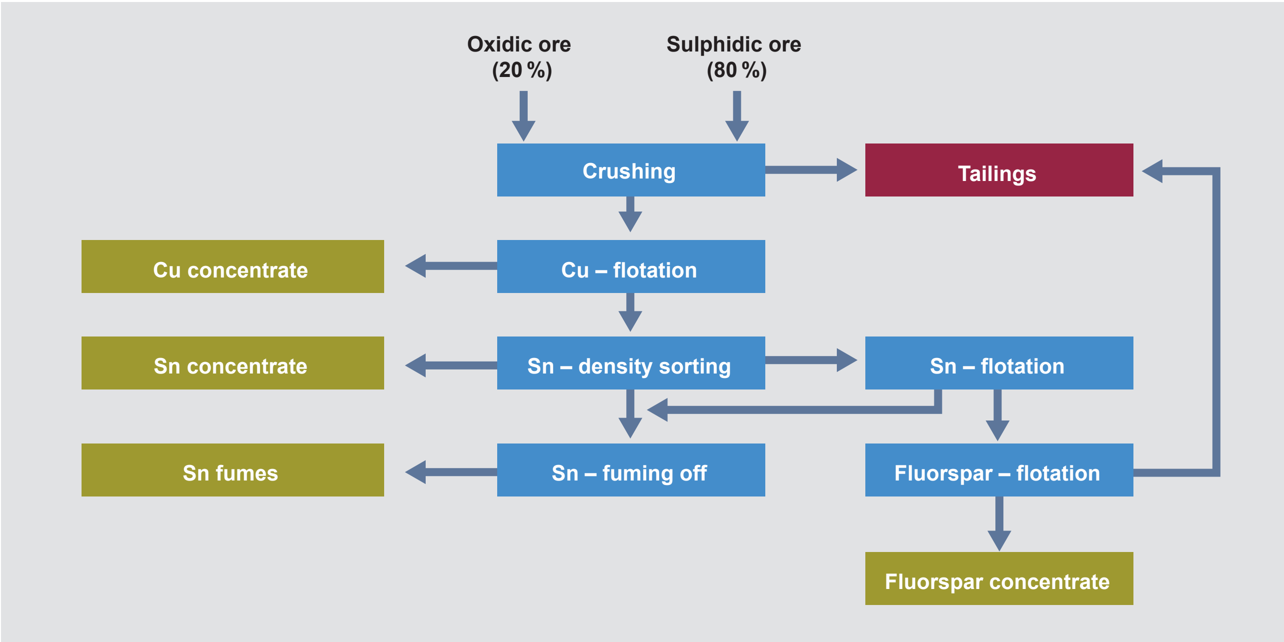


Fig. 5: *Example of processing a fine-grained, complex tin ore*

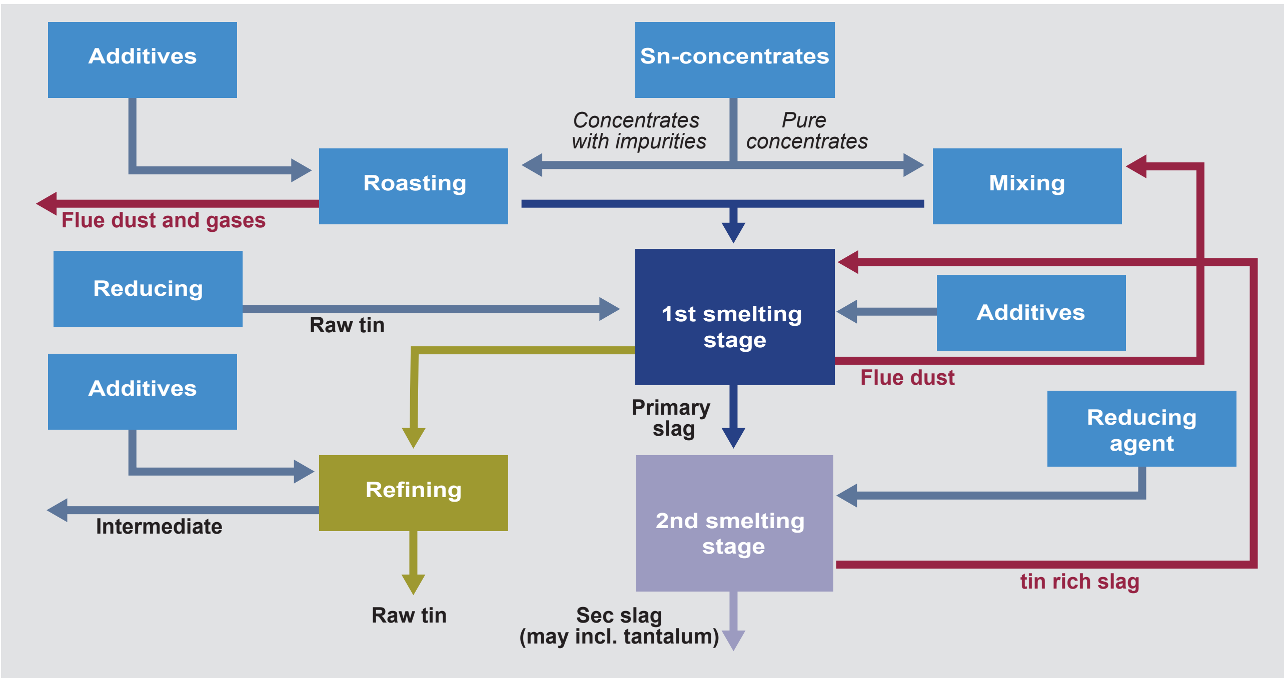


Abb. 6: *Tin smelting schematic for simple, rich tin concentrates.*

4 SUSTAINABILITY ASPECTS OF MINING

4.1 Environmental aspects

Land use

Primary tin ore deposits are often found in veins and are generally steep dipping bodies with large dimensions in depth and length and relatively thin, or they occur in the earth's crust as three-dimensional, extensive deposit bodies in which the tin minerals are finely distributed (disseminated). In general, the tin ore veins are mined underground, but can also be extracted in open-pit mining near the surface and when heavily weathered (Fig. 7). The International Tin Association (ITA) calculated for 2010 that around 56 % of global tin production comes from underground mining and 6 % from open-pit hard rock mining operations. The remaining 38 % of tin production comes from on- and offshore placer mining [6]. These figures remain largely accurate at the moment.

Large-scale ore bodies with disseminated mineralisation, which have a lower tin content than the veins, are generally extracted in open-pit mining operations or underground using block caving methods. The surface is impacted by the open-pit mine itself together with the required waste rock dumps or, in the case of block caving, by the depressions created by surface subsidence.

In underground vein mining, land is used by the required surface facilities, which can be dismantled after operations cease. Here, too, an additional land consumption factor are waste dumps, which are used to stockpile the accumulated barren rock. In some mines, this material can be utilised underground again by backfilling the mine, leaving less residual material on the surface. Land use is usually greater in conventional open-pit mining, because larger external waste rock dumps need to be established close to the operational areas. Globally, however, tin mining land use is lower than for iron, copper, nickel or aluminium, for example, due to the overall lower annual production.

The mean annual capacity of industrial ore processing operations worldwide is between 400,000 and 800,000 tonnes of ore. This means that, depending on the content and the enrichment factor, between 390,000 t and 780,000 t of fine-grained tailings must be deposited above ground or moved underground for backfilling. Calculated on the basis of the total annual global production of tin from hard rock (assuming a 20 m high tailings pond and a density of the mud-like tailings of 2 t (dry)/m³), this would correspond to an annual land consumption by tailings ponds of approx. 0.5 km².

The secondary tin ore deposits, also called tin placers, are mined on land, but increasingly also offshore, i.e. in the ocean. Mining tin placers is land-intensive, because the placers are sedimentary deposits that occur in relatively thin layers. In many cases, because tin placers have often formed in riverbeds or former riverbeds, economically used land or valuable natural habitats are disturbed by mining and endangered by erosion.

Tin placers on shore are often mined in so-called gravel pump mines or, to a lesser extent, by dredging in artificial lakes. The share of these operations in total global tin mining was approx. 17 % in 2010 and currently remains at approx. 12 % (around 38,000 t/a) [4]. The minimum content for recoverable placers on land is 100 – 150 g Sn/m³. The proportion of valuable heavy minerals, which also includes cassiterite, is relatively low in the placers. Due to the relocation of natural soil sequences in the course of placer extraction and processing, which is associated with an increase in soil volume (swelling), the original topography and the natural soil bedding conditions can no longer be restored. As a result, tin placer mining often leaves an unordered landscape that is difficult to recultivate. The average thickness of the barren overburden of onshore tin placers, for example in Indonesia, is estimated at 2 – 4 m and the average thickness of the placer at 3 m.

Tin has been industrially mined on the Indonesian islands of Bangka and Belitung using gravel pumps and water cannons for over 120 years. A large proportion of the island area (extrapolated at around 1,000 km² for a total area of around 16,400 km²) is therefore criss-crossed by abandoned mines and old mining waste.

The volume of unconsolidated rock moved ashore by gravel pump mining is estimated to be around 256 Mm³ annually, which in terms of mass, given an assumed specific weight of 2 t per m³, corresponds to roughly twice that of sand and gravel production in Germany (approx. 260 Mt per year). With regard to Bangka and Belitung, the organisation Friends of the Earth assumes approx. 54 km² of land is used annually for mining purposes [7].

Environmental protection and recultivation requirements in the Southeast Asian countries, where a large proportion of the tin placers are located, have only improved in the last few decades. Manual placer mining is a centuries-old tradition here, and industrial placer mining has been practised since the end of the

Fig. 7: *Open-pit tin mining on the island of Bangka, photo: BGR.*

Fig. 8: *Exploration by artisanal miners in a previously recultivated plot owned by PT Timah, photo: BGR.*

Fig. 9: *Floating chain-and-bucket dredger off the Bangka coast. Photo: BGR.*

19th century. This explains, in part, that the recultivation of older mining land, if done at all, was of poor quality. Now, recultivation of the excavated onshore land in Indonesia, Thailand and Malaysia is a legal requirement. However, until recently, the requirements for the planned recultivation projects were seldom met by the mining companies. Recultivation results were also often poor, because erosion control measures and the plants selected for recultivation did not meet the necessary requirements. Mining alluvial tin placers in the interior of the islands also degrades soil properties. The humus and nutrient content in the washed soils is low and the nutrient supply to the plants and the mass balance on the land intended for recultivation are therefore impaired. Between 2017 and 2019 BGR developed a recultivation manual, together with Indonesian experts, as part of a scientific pilot project, which aims to help improve recultivation performance in Indonesian onshore tin mining [17].

A particular problem for recultivation in Southeast Asia is illegal post-mining by artisanal miners on previously recultivated land. Because residual tin stocks are suspected, recultivated land is repeatedly excavated again by small-scale mining (Fig. 8). The land that has been disturbed by post-mining is not subsequently recultivated because of the lack of money and awareness in small-scale mining.

Use of the sea

Currently, offshore mining of tin placers continues to be extremely important. Around 20 % of global tin production in 2010 came from suction dredging or excavation of the seabed using mechanical dredging methods (Fig. 9) [6]. However, because part of the Indonesian suction dredger fleet has since been decommissioned this share has decreased significantly. At the PT Timah tin mining company in Indonesia alone, approx. 17,000 t of tin was produced by offshore extraction in 2018. In addition to PT Timah, other Indonesian companies also extract tin placers offshore using suction dredgers. In this process, the sea floor is disturbed over large areas.

The minimum concentration for recoverable placers offshore in Indonesia is approx. 250 g Sn/m³ and the average thickness of the tin-bearing horizon is up to 10 m [12]. An average tin placer covering of 10 m overburden can be assumed. Under these assumptions, PT Timah alone would need to mine a seabed area of approx. 6.8 km² annually in Indonesia and relocate a total volume of 136 Mm³ of seabed. Because industrial dredging is only allowed outside a 2 km limit to the coastline, artisanal offshore mining operations have established themselves within this 2 km zone, which is also highly prospective for tin (Fig. 10). As a result, the seabed area affected by offshore extraction is likely to be considerably larger than 6.8 km² annually. Extrapolated to a share of approx. 15 % of global tin production, global tin placer dredging would annually cover up to 15 km² and move up to 300 Mm³ of sea floor. In comparison, the total volume of sand and gravel extraction in Germany is around 160 Mm³ [8].

Emissions

The mineralogical composition of the ore and the geology of the deposits mean that the environment could be polluted by acidic water or by increased radioactivity. Experience from Nigeria, the United Kingdom (Cornwall) and China, but also the Erzgebirge in Germany, show that certain tin deposits (especially pegmatites and greisen type) display a close link between tin mining and radiation exposure in the environment, because the naturally occurring radioactive radon gas is only released as a result of mining activities.

In addition to tin-stone, other heavy minerals such as monazite and zirconium, both of which contain radioactive elements (uranium and thorium), are enriched in the pre-concentrates of tin from placer mining. Therefore, once the tin-stone has been separated in heavy mineral processing, the remaining by-products of processing should be temporarily stored or disposed of according to their radiation properties (Fig. 11). Because monazite and zirconium have a market value, the larger processing operators each check whether the monazite and zirconium concentrates can be sold directly or processed further into intermediate products. In Thailand and Malaysia, in particular, processing tin placers resulted in radioactively contaminated heavy mineral dumps that then required remediation in the 1980s and 1990s.

In Indonesia, research on leaching monazite concentrates in order to extract rare earths from them has been undertaken in recent years.

Acid mine water is mainly caused by the oxidation processes of sulphidic minerals that come into contact with oxygenated water either in the rock itself or during processing. The principal mineral cassiterite is an oxide and therefore does not have its own acid potential. However, some deposits also include tin sulphides, formed in conjunction with other sulphide minerals and which have a certain acid formation potential. Tin deposits generally have only a weakly acidic character, if at all.

***Abb. 10**: Cluster of suction pumps installed on fishing boats off the coast of Bangka, photo: BGR.*

***Abb. 11**: PT Timah monazite concentrate store. Warnings against possible radiation are absent; however, there is a warning that smoking is harmful, photo BGR.*

Biodiversity

Coral reefs can be directly damaged by offshore extraction. In contrast to other marine fauna, coral banks consist of stationary living beings that perform a variety of functions in the ecosystem. Offshore tin placer mining only leads to recultivation measures on a small scale, such as the resettlement of corals, if coral banks have been damaged by mining.

An environmental impact assessment is usually carried out in all tin mining countries before commencing onshore and offshore mining. There is an obligation to monitor offshore extraction activities from an environmental perspective and to assess biodiversity developments in the mined areas after completion. However, this practice does not have any real-time benefits, as it is assumed that restoring the original biodiversity or an equivalent area will only be possible after a long period of time, if at all.

Offshore tin placer extraction also exercises a long-range effect on areas not directly affected by mining. Seabed extraction or placer processing and throughput of the overburden layers on board the dredgers, followed by subsequent tailings and waste dumping, creates a cloud of turbidity that propagates with the ocean currents. The fine soil particles in the suspension settle very slowly in the calm water and, when settled out, can damage flora and fauna such as corals at some distance from the extraction point. It is generally assumed that the biodiversity in the vicinity of offshore extraction is also decreasing for this reason.

A study by the University of Bangka assumes that 50 % of the corals around the island of Bangka, which is at the centre of Indonesian offshore tin mining, are already damaged [9].

Because mass movements in hard rock tin mining in other tin mining countries are relatively low, the effects on biodiversity are comparatively small, here.

The coastline of the Indonesian tin islands has been modified by degradation and deposition of silt caused by dredging in the course of offshore tin extraction near the coast. The ecosystems were negatively affected along up to 70 percent of the Bangka and Belitung coastlines, especially corals, seaweed and mangroves.

4.2 Social and socio-economic relevance

Due to the high proportion of small-scale mining in tin production (this proportion is estimated by BGR at approx. 27 % of total production), commodities extraction contributes to economic development in less developed and rural regions by creating income opportunities. Small-scale tin mining is found mainly in Southeast Asia (a proportion of production in Indonesia and Myanmar), Central Africa (Rwanda, Burundi, DR Congo), and Brazil and Bolivia. It is believed that more than 250,000 people work in small-scale tin mining operations (industrial small-scale mining and artisanal small-scale mining). Working conditions in small-scale mining are often critical, especially with regard to occupational safety and health. Collapsed underground mining tunnels are repeatedly reported from the artisanal mining sector in Central Africa; they frequently report dozens of buried or trapped miners [10].

Artisanal production is not necessarily illegal, but it may be outside of the law for various reasons. Informal mining, for example, often takes place without state licence, but is partly tolerated or carried out on third-party concessions with or without the consent of the owner.

In Southeast Asia, mining in unconsolidated rock also leads to more accidents in improperly secured mining operations, on one hand by small-scale miners who carry out risky post-mining operations and on the other by residents who are not aware of the dangers of the abandoned and unsecured former mines. Landslides near open-cast pits in alluvial or weathered rock are also quite common.Around 90 % of the value of refined tin production is passed on as net proceeds from the smelters to the mining sector in the respective country; only approx. 10 % of the added value remains at the smelter locations. Tin mining revenues can be substantial at all government levels. The value of the refined tin (approx. 45,000 t) produced by PT Timah on Bangka and Belitung in 2018 was approx. USD 0.9 billion. The value of the entire Indonesian tin production is approx. USD 1.5 billion. The value of the tin mining royalties for Indonesia alone would be approx. USD 45 million. Added to this are the taxes on tin mining company profits and, in the case of the semi-public PT Timah company, the corporate dividends

4.3 Governance

Almost all global production comes from countries with medium to weak governance (mean value of the world governance indicators < 0.5 [13, 14]; Fig. 12). Myanmar, in particular, assessed as having poor governance, has grown into the third largest tin producer in recent years. Tin extraction comes primarily from the so-called „Wa State“, an autonomous region in Shan State in Myanmar. The Wa Army has been identified by the United Nations as a conflict party that has not taken any action whatsoever against the use of child soldiers. This implies corresponding due diligence risks for supply chains from this region [11]. In 2011, the International Tin Association (ITA) established the ITSCI (International Tin Supply Chain Initiative) for supply chains from conflict and high-risk areas that require traceability and increased risk management in accordance with the OECD guidelines. This includes barcode labelling the supply chain from mining to smelting and risk monitoring locally in the producing countries. The system has been gradually expanded and is currently being used in Burundi, the DR Congo, Rwanda and Uganda for supply chains for tin, tantalum and tungsten.

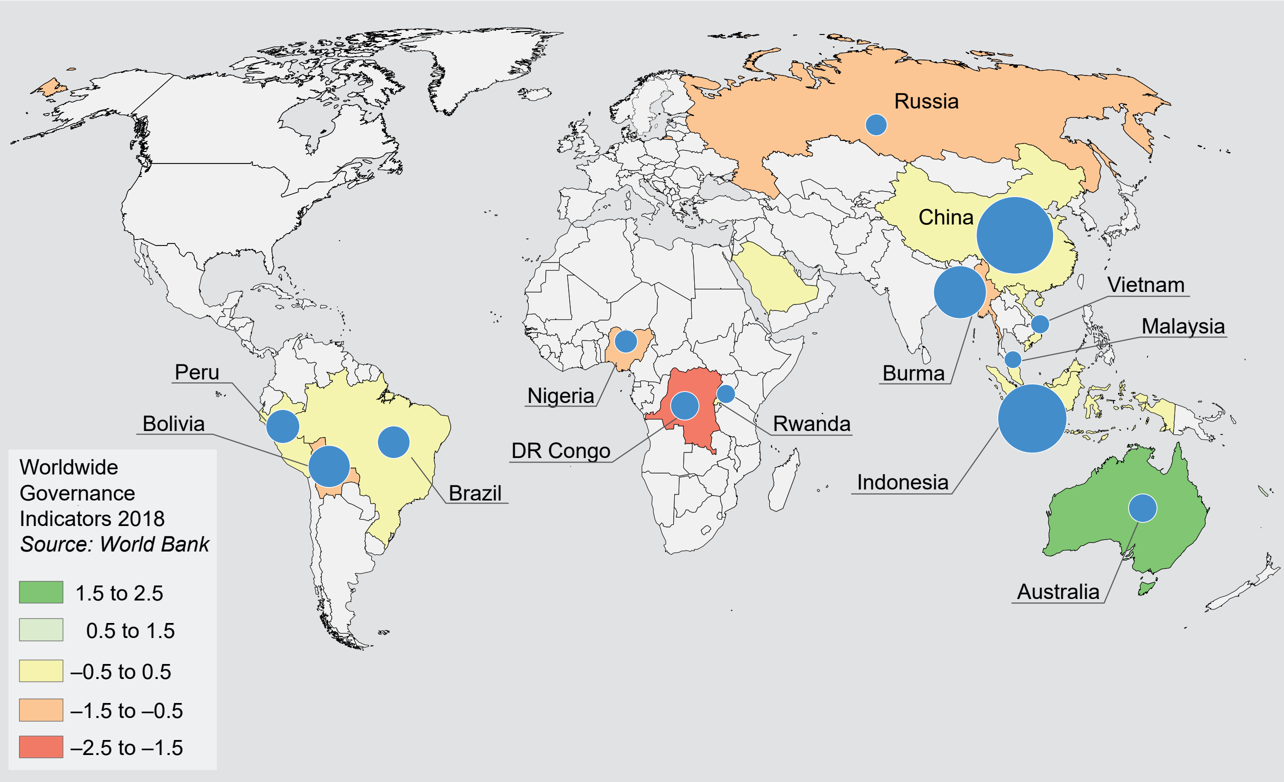


***Fig. 12**: Governance of the principal mining countries for tin production, 2018, [13], blue circles indicate the scope of tin extraction by mining in 2018 (total production 2018: 323,000 t tin content), [3].*

The ITA has established a policy for responsible resource extraction (Code of Conduct, [15]). The companies are assessed (with the participation of external experts) in accordance with the 10 principles and 70 standards in the sustainability reports and the assessments are publicly available for 10 of the 11 companies. Member company Minsur (Peru) is also a member of the ICMM (International Council for Mining and Metals), an international mining association that inspects its members for compliance with sustainability principles.

5 SUSTAINABILITY ASPECTS OF PROCESSING

Both pyrometallurgical and hydrometallurgical processes are used to refine the crude tin. The general disadvantages of the pyrometallurgical processes compared to the hydrometallurgical processes are the poorer tin yield, the complexity of the process and the higher demands on occupational safety. Semi-continuous electrolytic tin refining in the hydrometallurgical process is less complex, but has a lower throughput rate. At approx. 350,000 t (2018), the volume of tin refined worldwide, and the associated impacts, are fairly small compared to other base metals (copper approx. 20.5 Mt, iron approx. 2.2 billion t of iron ore).

5.1 Environmental aspects

Emissions

If sulphides are present in the tin concentrates, they are roasted. The purpose of the roasting process is to convert the sulphides into oxides or to pre-refine them, by which means arsenic or other metal oxides (bismuth, lead, antimony), for example, are volatilised or impurities are oxidised in such a way that they can be removed by leaching. Among other things, the roasting processes produce sulphur dioxide as exhaust gas, as well as flue dust, which can pose a hazard to workers or the environment. Filtering the process exhaust gases is necessary for economic as well as environmental reasons.

Energy sources and demand

The following input materials and energy are required to produce 1 t of crude tin:

- Reducing coal: 220 – 290 kg (approx. 15 – 20 % of furnace charge for a 70 % Sn concentrate.)
- Fuel oil 110 – 145 kg
- Large amounts of electrical energy are used for reduction in an electric furnace: 1,300 – 1,860 kWh (4,700 – 6,700 MJ)

Taking into account the specific carbon dioxide emissions of various fuels, these input quantities mean that around 2 – 2.5 t CO_2 per tonne of refined tin are directly emitted.

Residues

The amount of primary slag that ensues from a pure tin concentrates is between 150 and 200 kg per tonne of crude tin. Seen globally, at least 45,000 – 60,000 t of primary slag is therefore produced annually. Because the primary slag still contains a lot of tin (8 – 25 %), it must be processed in at least one further process stage. Recovery of the tin from the primary slag can make up 5 – 10 % of the total tin feedstock and can be achieved in one or two process stages.

The final quantity of secondary slag to be disposed of from tin smelting is low and is between 35,000 and 50,000 t globally. The final slag contains predominantly iron oxide and silicon dioxide as well as calcium, aluminium and magnesium compounds, and is therefore harmless. The tin content of the secondary slag is < 1 %.

In addition to the slag, there is also the flue dust (3 – 5 (max. 10) % of the concentrate), which consists to a large extent of tin compounds (40 – 70 %), but also of heavy metals (arsenic, antimony, lead, bismuth), and iron and other metal oxides. The flue dust is captured in bag filters and normally returned to the smelting process after briquetting or pelletising.

The total tin yield from concentrates with a high tin content is over 99.6 % and can drop to 92 % for low-percentage concentrates. Real tin losses can only be found in the disposable slag, possibly in other landfill products and in the fugitive dust losses.

Some slags can contain around 10 % niobium-tantalum oxides, which can be recovered from the slags through further processes. Tin slag is therefore an important source of tantalum (approx. 9 % of global tantalum production).

5.2 Governance

Of the ten largest tin smelters in the world, seven are in Southeast Asia and two in South America. The Responsible Minerals Initiative‘s certification program, the Responsible Minerals Assurance Process (RMAP), also certifies tin smelters (which process ore concentrates, not recycling smelters) with regard to compliance with the OECD standard for raw material supply chains from conflict and high-risk areas [11]. This primarily includes human rights and conflict-related risks (e.g. child labour, armed groups funding). The programme currently includes 78 smelters, 37 of which are in Indonesia and many of which are no longer in production, meaning that around 60 active smelters can be assumed. Around 80 % of the smelters are currently certified in accordance with RMAP or are in the process of being audited [14].

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