Controversial Materials

Ethical issues in the production of mineral based raw materials

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Abstract

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This report has investigated the ethical issues associated with mining or processing of materials that make them considered as controversial. For each material, the main areas of use and the top producing countries are analysed, followed by social and/or environmental issues as well as potential problems in the future. In total, 13 materials are discussed, of which most are minerals. The overall issues, that are recurring throughout the report and are important to be aware of are: child labor, low safety standards, mining activity resulting in deforestation or harming biodiversity, mining processes that affect communities (e.g. because of large water consumption) and the risks associated with widespread illegal mining. The report also provides research about organisations and initiatives that aim to affect the problems, and gives a brief view over tools that can be used to increase awareness of these issues.
Acknowledgements

This project was initiated by and performed in cooperation with ABB Corporate Research. We would like to thank them for their assistance throughout the project. We would also like to express our gratitude to the people that have contributed to the implementation of this project: To our technical supervisor Mikael Höök that has provided us with valuable information regarding the contents of the report, and to our project in general; supervisor David Sköld who has assisted us with useful pointers for the project. A special thanks to Kathleen McCaughey at Amnesty International for providing up to date knowledge about ongoing human rights abuses and to Chris Bayliss at the International Aluminium Institute for the helpful information received regarding the issues associated with the processing of certain materials. We would also like to thank the numerous organisation mentioned in this report for their initiatives regarding the issues addressed in the report, without them this project would not be possible.
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Introduction

With the rise of the technical advancements that have been ongoing in recent times due to e.g. increasing knowledge and a rising market for electric vehicles, new materials are constantly emerging as possible alternatives for a wide variety of applications. The huge demand for raw materials today has led to a vast increase in mining and extraction sites, which are having a huge environmental and social impact. Unfortunately, there is an immense ignorance and in some cases sheer mismanagement in the mining and refining industry with well documented exploitation of locals and negative environmental effects. Even though there are laws regulating certain materials (e.g conflict materials), it is often legal for companies to obtain raw materials from ethically questionable sources.

Which raw materials that are used in products and how they are sourced are both incredibly important factors affecting the impact of a company’s supply chain. Supply managers of manufacturing companies are experts in supply chain related issues and are responsible for ethical sourcing. However the groundwork for minimizing the negative impact of a supply chain is done when selecting materials during the development of new products. This report is directed towards the Corporate Research Function at ABB and is meant to assist them in making those choices. There are a multitude of factors that have to be taken into account in making these decisions that we, authors, are not informed in. Therefore we felt that the best way to help ABB Corporate Research is simply to give an overview of the issues surrounding a number of materials that could be candidates for use in their products. These overviews will serve as a quick way for researchers and engineers to get to know where caution is due and where investigation is needed to make an informed and ethical decision.

The aim of the project is therefore to inquire information regarding these controversial materials and the circumstances of their extraction and harvesting. Furthermore, the project seeks so generate a list of materials that today are contributing to negative environmental and social effects. The aim is not to stop the sourcing of materials from the problematic areas, but rather to address ethical issues associated with them. In some countries the mining industry is crucial for the people’s economical income, and therefore it would be preferable to help the workers and environment, if that is possible.

Over the last ten years, the way that issues around raw materials extraction have been discussed has changed and attention has increased immensely. Markets are changing constantly and several developing countries, primarily in Asia, have just recently started trying to reduce environmental impact from their industries. Due to the constant change of the mining industry, including relevant mining and refining technology, laws and regulations, as well as demands, knowledge and reserves, this report reliability will decrease with time.

Definitions & Delimitations

The final report includes a list of raw-materials that are ethically controversial, because of social or environmental issues associated with their extraction or harvesting. Conflict minerals are not included.

**Raw-materials** refer to materials that have not been processed. The aim is to find materials that can be used by ABB in their product development. This means that a lot of materials can be of interest, including metals and minerals, plastics, oils and possibly chemicals used in industrial processes. This report however does only include metals and mineral raw materials. This is because these have a large part of their impact closely connected to extraction and also relatively simple supply chains compared to oil based products and most industrial chemicals, making it easier to draw meaningful conclusions on the impact of their usage. Additionally mining generally has a large local environmental impact that is easier to quantify than impact from for example farming and energy production, that is often discussed from a global perspective. The mining industry is also blemished by many cases of human rights abuse that it is important to raise awareness of.

The **social** problems are limited to activities interfering with democracy, preventing prosperity, financing criminal activity or violating human rights. In human rights, numerous circumstances are included, e.g. low salaries, dangerous/harmful conditions, forced labor or child labor.

The **environmental** issues are mainly focused on local impact, and include acidification, heavy metal waste, toxic emissions or damage on biodiversity.

The focus is on problems during the **extraction or harvesting**, and possibly the initial steps of refining. The idea is to give ABB an overview of the materials they purchase. Therefore, potential issues associated with further process-
ing, performed by ABB, are not accounted for.

The report does not include conflict minerals, also known as ‘3TG’ (Tantalum, Tin, Tungsten and Gold) which are covered by the Dodd-Frank Wall Street Reform and Consumer Protection Act.

Every material analysis includes the following:

- A brief description of the material and possible usage for ABB.
- A description of the geographical situation of the material extraction, and the local impact.
- A summary the attention the issues have gained, including NGO’s campaigns, and/or if there are any initiatives whose objective is to improve the problem.
- A analysis of the future for the material, including topics as availability, price, problems and recycling.
The method used to gather information went primarily through gathering information from online sources including scientific reports, non-government organizations, media, companies and industry analysts. Some interviews were also arranged with organizations that were considered relevant for the problem, both in person and through Skype.

Firstly, five close-by organizations were contacted by phone with the aim of organizing a meeting with each organization. The organizations were as follows: Greenpeace, Amnesty, WWF, Sida and SEI. A meeting was set up with Amnesty, while the rest of the organizations were contacted through e-mail instead. Organizations that were out of reach for setting up a meeting were e-mailed directly.

While waiting for answers by e-mail, online research took form to investigate which materials could be candidates for the project and if there are any present regulations regarding e.g. mining safety and child labor. ABB were not interested in conflict materials with existing laws, leading us to define the meaning of a conflict material and where they exist. Critical materials were a starting point of which the group began their first selection of materials.

The gathered information regarding potential controversial materials, including a brief summary, potential uses and issues, were e-mail and discussed back and forth with ABB to ensure that the materials were relevant to the ABB corporate research group. This procedure was repeated several times during the whole project. The goal was to include a total of at least 15 materials in the report.

Five of the accepted materials were distributed among the group members, where each group member was responsible for one material for further investigation. The research included answering all of the questions in section 2.1, further analyzing environmental and ethical issues. Two of the investigated materials were chosen for a half-time report and presentation.

After the half-time report was due and the presentation was done, the group received some constructive critique from an opponent group regarding the work so far and issues to consider more. The project was also discussed together with ABB again to refine some of the focus of the material research as well as adding another question regarding the future for each material.

Each group member was then given two materials each to investigate further, in the same method as previously. The work was then organized further, creating templates and analyzing the work of all the group members.
1. Aluminium

Introduction

Usage
Aluminium is one of the most commonly used technical materials. It is the third most abundant element on earth, and the most abundant metal. Due to its low density, aluminum is versatile in its usage and is used in large volumes in automotive and aerospace industries, for packaging as well as electronics and greater constructions [1]. In Figure 1.1, the world usage of aluminium is showed.

Figure 1.1: Areas of use in 2011 [2]

Production
Bauxite, the ore aluminium is extracted from, is firstly mined in a certain area and later often shipped on further, were the aluminium is refined. Bauxite contains 40-60 mass-% of aluminium, where the rest of the mass includes some percentages of iron oxide, silica and titanium [3]. Australia, Canada, China, Russia and the US are the largest producers of aluminum. Whereas Australia, Brazil, China, Guinea and India are the main producers of Bauxite [4]. The main extraction sites by country is displayed in figure 1.2, where as the percentage per country is shown in table 1.1.

Table 1.1: Estimated world production in 2016 [5]

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>53%</td>
</tr>
<tr>
<td>Russia</td>
<td>6%</td>
</tr>
<tr>
<td>Canada</td>
<td>6%</td>
</tr>
<tr>
<td>India</td>
<td>5%</td>
</tr>
<tr>
<td>UAE*</td>
<td>4%</td>
</tr>
<tr>
<td>Australia</td>
<td>3%</td>
</tr>
<tr>
<td>Norway</td>
<td>2%</td>
</tr>
<tr>
<td>Others</td>
<td>21%</td>
</tr>
</tbody>
</table>

*United Arab Emirates

Issues

Forcibly Moving Indigenous People
Bauxite smelting is an extremely energetic process. When creating one ton aluminium, four tons of bauxite are consumed. The aluminium extraction is also a quite space consuming process, which historically has caused native people to be displaced. [4].

Red Mud
The main waste product from aluminium production is “red mud”. Red mud is a toxic and corrosive product that consists of iron-, titanium- and nitrogen oxide. The mud also contains heavy metals such as arsenic, chrome and mercury[6]. The yearly amount of refined bauxite is approximately 110 million tonnes, resulting in 150 million tonnes of red mud annually, and approximately 5-6 million tonnes in Europe[7].

Not only is red mud toxic, but the safety standards for the storage is questionable. On the 4th october 2010, a dam of red mud from an aluminium plant burst in Hungary, killing 10 and injuring over 120 people[8]. A total of around 7000 people were thought to have been directly affected by the catastrophe[9]. Over one million cubic meters of red mud was released into the environment, destroying villages nearby, forcing some houses to be bulldozed to the ground. The accident was in 2011 named “Hungary’s worst ever industrial catastrophe” [8].

Health Risks in Malaysia
In Kuantan, Malaysia, the mining area lays close to school and populated areas and it is said to be much more illegal individual miners than the legal ones [10]. Due to shut down
of Indonesian mines, Malaysian mines were created at a fast pace and a lot of non-licensed miners were suspected. Malaysia was the biggest bauxite exporter in the world and were exporting half of China’s aluminium production [11]. Thus after reports of several misfortunes in the Malaysian mining areas the mining was preliminary banned to mid 2017.

**Attention & initiatives**

**Greenpeace**

Greenpeace have started demonstrations with around 50 activists that have blocked the entrance to the Chilean Presidential Palace demanding the government to protect the forest in Patagonia, Chile. The mining company NORANDA wants to expand by creating an aluminium mine, using thousands of hectares of the ancient forests [12]. According to Greenpeace, the project called Alumysa that NORANDA want to execute would cause a flooding of 10,000 ha of forest releasing over 500,000 tonnes of toxic waste a year, as well as polluting the air [12].

**Clean Malaysia**

The news site “Clean Malaysia” focuses partly on the environmental issues in Malaysia, including the mining industry. The World Health Organization (WHO), United States Environmental Protection Agency, and Malaysian water quality standards (INWQS) does have guidelines for what concentration of different pollutions are estimated to be acceptable [3].

**Outlook**

Due to aluminium’s non-criticality, substitutes for aluminium is probably not that relevant to discuss. Although, if there are problems surrounding the extraction, there are still some substitutes for different applications. According to the European Commission [13], the substitutes does not have the exact properties as aluminium and can therefore not be considered to simply replace aluminium directly. The demand of aluminium is therefore expected to always be high.

**Recycling**

As the global demand is expected to increase by 300% the mining part of the aluminium supply is estimated to go from 55% 2012 down to 30% by year 2080 [14] due to recycling. When recycling aluminium the energy saving is 90%. Therefore this is preferable to production from mining.

**References**

2. Chromium

Introduction

Usage
Chromium is one of the most critical and strategic materials in the world having a wide range of uses predominantly in the metal and chemical industry. The metallic substance is probably mostly recognized by its use as chromium plating with its characteristic mirror-like appearance. However, the main application for the material today is as an alloy component in stainless steel owing to the exceptional corrosion resistance that chromium provides. The metal is also distinguished by its relative high hardness, high melting temperature and great refractory properties making it a potential material choice in a wide variety of applications [1].

Production
Chromium is extracted primarily through the refining of chromite ore. The top world extractor today is South Africa which has about 40% of the total world production, other notable extractors are Kazakhstan, India and Turkey. It is estimated that about 95% of the world's chromium resources are geographically situated in Kazakhstan and southern Africa and are calculated to last for centuries ahead [3].

Table 2.1: Estimated world production in 2016 [3]

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africa</td>
<td>46%</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>18%</td>
</tr>
<tr>
<td>India</td>
<td>11%</td>
</tr>
<tr>
<td>Turkey</td>
<td>12%</td>
</tr>
<tr>
<td>Others</td>
<td>13%</td>
</tr>
</tbody>
</table>

Issues

Environmental Effects
Owing to chromium’s toxic nature it is viewed as a potential hazard for the environment, the use of the metal creates numerous environmental issues linked to inevitable waste products from mining and postmanufacturing slag piles.

Unfortunately, the management of waste products in the industrial world are often problematic and leaks do occur, ultimately leading to soil and groundwater contamination [4]. The negative health effects from especially hexavalent chromium to humans and other biological creatures are immense; it is known to be highly toxic, carcinogenic and mutagenic to living organisms. Hexavalent chromium, Cr(VI), is chromium in its +6 oxidation state and can be discharged into the environment from waste rock, dust and chromium ore processing residue.

The substance enters the body through inhalation, skin contact and ingestion and is dangerous even in low concentrations, it is therefore of the utmost importance to minimize the emissions of particularly hexavalent chromium into the environment [5].

Mismanagement in the Industry
Due to the vast amount of waste piles that gather up during the extracting and refining processes it is hard to avoid environmental pollution. However, companies can take responsibility for the waste, which minimizes the problem. This is a greater issue in less developed countries in general, and there are many examples of mismanagement around the mines and refineries that have led to environmental disasters. To mention a chromium-related example, the erosion of chromite waste rocks and overburden dumps in Zimbabwe.
has caused flooding, blocked channels, decreased oxygen content in the water and reduced the fish breeding ground capacity leading to a major impact on the local flora and fauna [6].

Problems in India
In 2007, Pure Earth, an international NGO, dedicated to solve pollution problems where human health is at risk declared Odisha in India as one of the most polluted places in the world. The Odisha valley holds the largest chromite deposits in the country with a number of operational and abandoned mines. Pure Earth stated that the air and soil of the area are so heavily affected by the leaching of hexavalent chromium that intestinal bleeding, asthma and birth defects have been common in communities surrounding the mines. Other studies has also shown that the death rates in the district are remarkably higher than the rest of India owing to chromium related afflictions [6].

Major Emissions in China
In India’s neighboring country China, which even tough is a small extractor of chromite ore from a global perspective, still generates the largest amount of chromium slag products worldwide [5]. In 2014, China was the largest producer of ferrochromium (FeCr) in the world, much of it derived from South African chromite ore [3]. Ferrochromium is the largest source of chromium in the stainless steel industry and is directly used in the application instead of refining it further to pure chromium [1]. It is estimated that the quantity of untreated slag products in the country has exceeded 400 million tons, these include waste from production of chromium based raw materials and the use of the metal in certain applications such as electroplating. This is of course a major risk enhancer and accidents are bound to happen.

In 2011 serious slag contamination was discovered in Qujing in the Yuan province where concentrations of hexavalent chromium in the Zhuijan river where about 2000 times higher the standards. The reason for the accident was due to the illegal dumping of chromium slag products in the mountains near the river source. The nearest village to the contamination root, the Xinrong village, today also known as “the dead village”, has had tremendous misfortunes since the leak. According to the villagers, some people have died from cancer as a result of the leak and a total of 77 cows and sheep suddenly died from drinking the polluted water [5].

Human Rights Violations in South Africa
South Africa which is by far the largest producer of chromite ore has 40% of the world total production. It is also a place where the mining industry still is under development regarding its environmental and social policies and is therefore prone to unethical extraction procedures. Different reports are suggesting that there are cases where locals are being exploited in the chromium mining industry, leaving them with little compensation relative to the performed labour. The Sekhukhunе district in the Limpopo province is an area with a rich chrome belt where violations against mining laws have occurred.

In late 2016 the Mail & Guardian, a recognized South African weekly newspaper, released a series of articles regarding illegal mining activities in the area. It was unveiled that certain investors have been mining in the area without mining licenses and leaving the people worse off than when they came. One of the investors was revealed to be Johan Niemoller, a former operative in the Civil CO-operation Bureau, also known as the apartheid death squad. The locals report that Niemoller came with promises of a better life and brought in costly machinery for the extraction of the chromite ore, but he never applied for a permit nor did he invest the hundreds of millions of dollars required for legitimate mining operations. Niemollers enterprise was eventually shut down by the government. However, he still managed to extract ore worth millions of dollars leaving the local community poorer than before [7].

Initiatives
China is trying to cope with the emission issues and are implementing strict laws on chromium waste. The company in question responsible for the leak in the Zhuijan river was immediately banned from further production activities [5].

Different initiatives from western countries have also been set out to help the Chinese government in the regulations of laws regarding the growing threat posed by chromium waste. Recently the U.S. based NGO EDLC was involved in a project aimed to assist Chinese civil society and share knowledge from the U.S. experience with chromium waste management. EDLC recruited a team of lawyers with the task to develop a report on the U.S. regulations of toxic and hazardous substances, mainly focusing on the treatment of hexavalent chromium. The report contained regulations and monitoring of toxics, federal laws to prevent toxic pollution and other guidelines to prevent further unnecessary emissions from the chromium based industry. The project was considered a success and trips were organized to meet civil society groups in China to further explain the U.S. model of toxic regulations. The report is also hoped to help the Chinese court in cases involving toxic waste contaminations [8].

Outlook
As chromium is a relatively common element in the earth’s crust, the supply of the metal is not threatened in the future. The reserves are as mentioned estimated to meet global demand for centuries ahead at current production and consumption levels. Available reserves of chromite are thought to be located up to 95% in South Africa and Kazakhstan and these countries should therefore continue to be the top producers, however, large quantities are expected to be produced in Turkey and India. Many of the ores containing platinum group metals (PGMs) have chromium as a co-product, where an increased demand for the PGM-metals may result in a increased production of chromite ore. The lack of a substitute for chromium in stainless steel or in certain superalloys will make chromium a highly demanded raw material even in the future and the metal is for instance labeled as a “critical raw material” by the European Commission [2, 3].
References


3. Cobalt

Introduction

Usage
Cobalt is a mineral that’s used in a large scale at an industrial level, where the main application is for rechargeable batteries and superalloys [1]. The demand for cobalt has risen the latest years in correlation to the increasing production of rechargeable batteries in electrical vehicles [2], where China stood for 80% of the total consumption and refining of cobalt in 2016. Some other areas of use are in cemented carbides, corrosion and wear-resistant alloys, magnets and catalysts [1], see Figure 3.1.

Figure 3.1: Areas of use in 2016 [2]

Production
The concentration of cobalt in the earth’s crust is approximately 0.002%, and is thus mostly mined as a by-product from nickel and copper [3]. Cobalt is produced in, decreasing order, Democratic Republic of Congo (referred to hereinafter as DRC), China, Canada, Russia, and Australia, where DRC stands for over 50% of the overall production [4], see Table 3.1 and Figure 3.2.

Figure 3.2: Map of world production in 2016 [4]

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRC</td>
<td>54%</td>
</tr>
<tr>
<td>Zambia</td>
<td>5%</td>
</tr>
<tr>
<td>China</td>
<td>6%</td>
</tr>
<tr>
<td>Cuba</td>
<td>4%</td>
</tr>
<tr>
<td>Canada</td>
<td>6%</td>
</tr>
<tr>
<td>Philippines</td>
<td>3%</td>
</tr>
<tr>
<td>Russia</td>
<td>5%</td>
</tr>
<tr>
<td>New Caledonia</td>
<td>3%</td>
</tr>
<tr>
<td>Australia</td>
<td>4%</td>
</tr>
<tr>
<td>Others</td>
<td>12%</td>
</tr>
</tbody>
</table>

Table 3.1: Estimated world production in 2016 [4]

Issues
The fact that cobalt has its main mining sites in DRC comes with many ethical complications. The Dodd-Frank act specifies four minerals as conflict minerals due to their enrollment in personal benefit from sources as weapons trading and other violent causes in eastern DRC. Cobalt however is not defined as a conflict mineral by law since it is not mined in conflict areas, but still has ethical complications in correlation to its mining [5].

Cobalt mining in DRC has been discussed on various news sites, where large companies such as Apple, Sony and Samsung have gotten critique from Amnesty for not following through with their due diligence. Amnesty has investigated the mining of cobalt in DRC, and concluded that there is ongoing child labour as well as dangerous working conditions during the cobalt mining process [6].

Child Labor
Amnesty has approximated that there are 40 000 children working in the mines in the southern DRC. The children whose parents can’t afford school fees work for 12 hours a day, carrying heavy loads and inhaling dangerous dust, to earn 1-2 US$ a day. Some children who attend school, work in the evenings and on the weekends to support their family. Many children also said that security guards and different mining companies had beaten them, or that they had seen other children been beaten, as well as security guards demanding money from them [7].

Health Risks & working conditions
Apart from the child labour and child abuse, all the miners are exposed to harsh working conditions. Cobalt dust is
toxic and inhalation can cause a deadly lung disease called “hard metal lung disease”, as well as asthma and decreased pulmonary function. Amnesty interviewed miners in the southern areas of DRC, where many miners said that they suffered from respiratory problems and pain from the heavy lifting. The miners are missing even the most basic equipment such as gloves and face masks, partially since there are no regulations for small scale mining [7].

The mining sites differ in size, but are mostly small holes in the ground that the miners dig themselves, stretching down to 10 meters underground. Many accidents occur due to the lack of proper equipment, causing tunnel collapses. From September 2014 to December 2015, 80 deaths were reported by Radio Okapi (DRC’s UN radio station), but the number is believed to be larger since many deaths go unrecorded [7].

**Attention & Initiatives**

These issues have been brought to light by several non-government organizations. In January 2016 Amnesty published a study regarding the working conditions of cobalt mining in southern DRC, which was brought to attention by news sites such as BBC and Daily Mail. The report traces a complete potential supply chain from the artisanal miners to big companies (e.g. Apple, Samsung & Sony) using cobalt in their products. However, Amnesty doesn’t have a direct campaign combating this issue. Instead, Amnesty’s idea is to research human rights abuses to influence governments, companies and decision-makers [8].

Is has also been announced in November 2016 that the OECD cooperates with the Chinese Chamber of Commerce for Metals, Minerals & Chemicals [CCCMMC] in launching a Responsible Cobalt Initiative. Apple, Samsung and Sony, along with many other large companies, are included in this initiative, together with the Government of DRC. The goal is to create an action plan in the following twelve months to address the social and environmental issues in cobalt mining, with the main focus on child labour [9].

There are many other organisations that address the problem of mining in DRC in relation to conflict minerals, but not as many organisations that aim to improve the cobalt mining industry. However, one organisation that looks into this is the Cobalt Development Institute [CDI]. The CDI has a complete webpage and initiative to “promote the responsible and sustainable use of cobalt in all forms” by creating a “sustainability profile”. The CDI are also involved with other organisations such as the Materials Stewardship activities of ICMM, and sustainability activities with Eurometaux. These organisations aren’t specialised in a certain metal, but addresses the whole mining industry internationally and in Europe respectively. The CDI are also currently investing in a study to develop a “Life Cycle Inventory” and a “Life Cycle Assessment” for cobalt to model environmental effects of cobalt production [10].

**Outlook**

Cobalt prices and supplies are a hot topic at this moment for its involvement in the electric vehicle industry. SIAS predicts that many car-manufacturers and electrical companies will be strongly dependent on cobalt, due to current expansion and developments of electric vehicles made by Tesla, Nissan, Apple and Maserati to name a few [11]. The growing battery market[12] is believed to create an inevitable increase of the cobalt price due to deficit supplies [13]. Edward Spencer, a senior consultant at CRU, estimated that the electric vehicle industry stood for 4% of the cobalt demand in 2016, a number that is estimated to rise to 16.9% until 2021 [14]. Both CRU and Macquarie estimates a cobalt deficiency of around 900 tonnes in 2017, and Macquarie forecasts a deficiency of 5340 tonnes in 2020 [15]. During the period December 2016 to March 2017 the cobalt price has risen by 64% from 30,000 $/tonne to 49,000 $/tonne, according to Stephanie Hernandez McGavin, a reporter at Automotive News[16]. Hernandez McGavin however also says that the electric vehicle industry isn’t as hot as firstly thought due to low gas prices.

ECobalt, a battery-grade cobalt salt producer, on the other hand says that the cobalt price is estimated to increase by 68% from 2015 to 2025 [16]. The increasing demand numbers doesn’t comply with the mining and production of cobalt. The U.S. Geology Survey shows an increase of cobalt produced from 110,000 tonnes in 2013 to 123,000 tonnes in 2015 [4, 17]; a 12% increase, but not sufficient to keep up with demand.

Verisk Maplecroft does global risk analyses, and released an article in 2016 stating that the Democratic Republic of Congo is considered the 4th most unreliable country to perform business with, whilst producing more than 50% of the world’s cobalt [18]. However, some cobalts is also recycled. The United States Geology Survey states that cobalt recycled from scraps reached 28% in 2015 and 30% in 2016 [4, 19].

**References**


4. Copper

**Introduction**

**Usage**

Copper is one of the oldest metals mastered by mankind and has been used for millenias. The metal holds a number of interesting properties such as great thermal and electrical conductivity making it a highly demanded material in the industrial world. Today it is mostly used in the electrical equipment sector. Other notable areas contain the construction segment such as plumbing, industrial machinery like heat exchangers and alloys including old well established alloys such as bronze and brass [1]

Figure 4.1: Areas of use in 2011 [2]

**Production**

The production of copper has been through a major increase during last centuries electrical revolution and around 95% of all copper ever produced is dated after 1900. The metal is extracted from different ores often containing iron, carbon, sulfur and oxygen and the refining process is dependent of the ore type [3]. Today the metal is produced all over the world, the biggest extraction and reserves are found in South America where Chile being the world’s top producer and Peru the second are contributing to about 29% and 12% of the global production respectively. Other notable producers are the U.S, Congo and China (see Table 4.1).

Table 4.1: Estimated world production in 2016 [4]

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Chile</td>
<td>28%</td>
</tr>
<tr>
<td>Peru</td>
<td>12%</td>
</tr>
<tr>
<td>China</td>
<td>9%</td>
</tr>
<tr>
<td>USA</td>
<td>7%</td>
</tr>
<tr>
<td>Congo</td>
<td>5%</td>
</tr>
<tr>
<td>Australia</td>
<td>5%</td>
</tr>
<tr>
<td>Zambia</td>
<td>4%</td>
</tr>
<tr>
<td>Canada</td>
<td>4%</td>
</tr>
<tr>
<td>Russia</td>
<td>4%</td>
</tr>
<tr>
<td>Others</td>
<td>22%</td>
</tr>
</tbody>
</table>

Figure 4.2: Map of major world producers in 2016 [4]

**Issues**

**Environmental Impact**

Copper is a natural occurring element and is widespread in the environment. Most of it leached from natural phenomena such as volcanic eruptions and windblown dusts. However due to the largely elevated production rates in recent times, the concentration of copper in the environment is vastly increasing. Because copper has a large tendency to bind to organic matter found in the soil, most of the copper leaks are found in the near vicinity of the pollution source. If the compound however reaches surface water it can travel large distances and thus creating more than just local issues. Soil that is highly contaminated by copper leads to a number of environmental issues including grounds with little biodiversity owing to the low chance of survival for most plants in these kind of conditions. This environmental consequence can be seen near factories handling copper waste including mines where the ore extraction takes place. Because of this, copper refining possesses a huge risk for farmlands [1]

**Health Risks**

Small quantities of copper are not harmful for humans, it is in fact an essential element for maintaining a good health. If the concentrations of the compound however reaches higher values, it can have serious health effects. Breathing in high levels of copper can cause irritation in the nasal and oral passages which is mostly a problem for the miners. Ingesting can cause nausea, vomiting and diarrhea and if the amounts of copper reach extreme levels the kidneys and liver are prone to damage, potentially leading to death [5]. Other biological creatures are also affected by elevated
concentrations of copper, its toxicity has lead to issues in the marine life resulting in increased mortality and reduced reproduction of fish, plants and other aquatic organisms [3].

South America
The effect of irresponsible copper mining can be seen around the Chuquicama mine in Chile. In late 2014, Chinadialogue; an environmental english-based NGO, released an article regarding the consequences of mining copper in the area. Pollution from the mine has been so extensive that an entire town of 25,000 residence had to abandon the region. The area was considered to be so contaminated that it was deemed unsafe for further human habitation. The mine is located in the Atacama desert and has had a huge impact on the very scarce water resources in the area, due to the water intensive refining process.

In its neighboring country Peru, Chinese companies are the main producers of copper. Chinadialogue states that they are known for their laxity regarding environmental aspects in the zone and in 2014 Peruvian authorities sanctioned one of the larger Chinese companies for pouring toxic waste in the rivers [6]. It is not the first time that the authorities have intervened against Chinese companies, in the 1990s another enterprise was fined US$14 million for failing to meet its promises to invest in the local infrastructure. The same company was later on in 2005, subjected to heavy protests by workers claiming that they were treated like slaves with salaries only US$13 a day for 15 hour shifts [7].

Violations in Myanmar
There are several cases where Chinese companies are involved in questionable mining operations in other countries. In February 2017, Amnesty International released a report regarding the poor working conditions in a giant copper mine co-owned by a Chinese enterprise in Myanmar, also known as Burma. Amnesty stated that the Myanmar authorities must immediately halt operation in the copper mine which is being plagued by continuous human rights abuses [8]. Owing to vast political changes in the country in recent years, the new government is seeking massive increase in foreign investments which has led to unsanctioned exploitation of local populations. The people living around the mines are under constant threat of forceful evictions, environmental hazards and unjustified legal oppression. Plans of increasing the mines perimeters another two thousand acres are ongoing which will force the resettlement of homes and farmlands for 141 families living in the area. The residence in the affected zone have little to say in this issue and are being prosecuted by national authorities for attending peaceful protests regarding the environmental and social issues the mine entails [9].

The report also indicates that environmental violations has occurred around the mine in Myanmar. Amnesty documented that the mining company failed to prevent the discharge of hazardous waste materials in 2015. The leak was first noted by farmers who reported it to the authorities, however the leaching continued polluting the lands for weeks afterwards and eventually lead to the devastation of crops from the farms.

This particular mining area is also more prone to environmental accidents than others owing to its location; the Letpadaung mine is in a zone known for its earthquakes and floods. This can lead to environmental disaster for the local communities. The company running the mine has acknowledged the potential catastrophic impacts such an event can have on the community but has failed to carry out an adequate environmental assessment. The lack of such an assessment exposes the local population to a great risk [8]. This is not the first time that Amnesty highlights the issues regarding the mining operations in the area, in 2015 there was a more extensive report named “Open for business? Corporate Crimes and Abuses at Myanmar Copper Mine”. Unfortunately little has been done to solve the issues addressed in the 162 page long report, some of them even dating back decades in time [10].

Further Problems with Chinese Owned Mines
Another report called “You’ll Be Fired if You Refuse” released by the Human Rights Watch in 2011 also highlights problems associated with Chinese owned mines in other countries, this time in a copper mine in Zambia. The report reveals that workers involved in the mining activities suffer from abusive employment conditions that fail to meet international as well as the domestic standards. Workers report of terrible health and safety standards in the mines which includes poor ventilation systems as well as bad protective equipment that can lead to serious lung diseases. Employees are treated unjust and can face the consequence of being fired if they refuse to do labour in unsafe places. Incidents and health issues caused by the working conditions are therefore not uncommon in the mine [11].

The Human Rights Watch later did some follow up research in late 2012 which indicated that some improvement had been made regarding the employee’s rights such as reduction of working hours and respecting the workers rights for freedom of association. However there was a lot more progress to be made as workers still were exposed to health and safety hazards as well as mistreatment from their Chinese supervisors including racial degradation [12].

Initiatives
Amnesty International and the Human Rights Watch has included recommendations in the reports mentioned in the text of what should be done to solve these issues. The recommendations include guidelines of what action all the different parties involved in the extraction and trade should make. This includes advice for the governments in question and suggested precautions foreign companies should make before buying raw materials from these sources [10, 11].

Forecast
The major world deposits are found in the Americas, especially in the southern regions which will probably still be the main production area in the future. The demand for copper is constantly increasing and some argue that “peak copper production” will be reached somewhere between the years 2025-2030. Because copper is a theoretically finite resource the peak yearly production will be reached
sometime. However, when this will happen is subjected to heavy debate. The main argument against a peak copper production in the near future is the constant discoveries of new copper reserves as well as more efficient extractions methods [3].

In 2017, the production is estimated to exceed the world copper demand by 160,000 tons (1%) owing to a increased production growth of 1.7% against a 1% growth in copper consumption [4].

China’s rapidly growing industrialization and urbanization will most likely lead to more Chinese actors on the market and today the country buys about 40% of copper produced annually. The nations increasing demand for the metal can be seen in China’s copper trade with Chile. In 2005 only 22% of Chilean produced copper went to Chinese merchants whereas the 2012 figures showed a major increase to 80%. [6].

References

5. Natural Graphite

Introduction
Graphite is a crystalline allotrope of carbon. Natural graphite mined as a mineral and is divided into three categories based on its degree of graphitization, that is how similar its structure is to that of ideal graphite. Amorphous graphite is of the lowest quality. Flake graphite is of high quality. Lump or crystalline graphite has the highest quality but is only produced in very small quantities in Sri Lanka [1].

Synthetic graphite can theoretically be manufactured from any organic material. In practice fossil based products are used as raw materials. High temperature and pressure is used to purify the carbon and transform it into graphite. Synthetic graphite can be manufactured to a very high degree of purity and graphitization. Additionally its isomorphism can be controlled. Natural graphite can be replaced by synthetic graphite in all technical applications. Synthetic graphite generally several times more expensive than natural graphite, but the price difference depends greatly on quality needs and manufacturing process [1]. In 2011 synthetic graphite contributed to 56% of the global market [2].

Usage
Natural graphites largest area of use is in the steel and metal industries. It is used in refractory materials, continuous casting ware, linings for molds and as carbon raisers in steel. Large amounts of both flake and amorphous graphite are used in this industry. There are many other sectors that use natural graphite, where the largest are lubricants, automotive parts, carbon brushes and batteries. For batteries, brushes and other electrical components only high purity flake graphite is used.

<table>
<thead>
<tr>
<th>Countries</th>
<th>% of World Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>66 %</td>
</tr>
<tr>
<td>India</td>
<td>14 %</td>
</tr>
<tr>
<td>Brazil</td>
<td>7 %</td>
</tr>
<tr>
<td>Turkey</td>
<td>3 %</td>
</tr>
<tr>
<td>N. Korea</td>
<td>2 %</td>
</tr>
<tr>
<td>Russia</td>
<td>1 %</td>
</tr>
<tr>
<td>Mexico</td>
<td>2 %</td>
</tr>
<tr>
<td>Others</td>
<td>3 %</td>
</tr>
</tbody>
</table>

Production
Asia dominates the world market on both flake and amorphous graphite. In 2012, flake graphite accounted for 55% of the global graphite production. Asia had 93% of the global production of amorphous graphite and 77% for flake graphite [2].

Following mining flake graphite is crushed and impurities are isolated using flotation methods. The product is then milled into a fine powder and separated by mesh size. The powder is purified of sulfur and trace metals. The flake graphite can then be processed further into spherical graphite, expanded graphite or graphene. Spherical graphite is especially important because it is used in large volumes in lithium-ion batteries, that consist mostly of graphite by weight. The production of spherical graphite uses a wet chemical process with low yield. It takes three tonnes of high grade flake graphite to produce on ton of spherical graphite [4].

Issues
Graphite mining and processing can cause serious pollution. It produces a fine graphite dust which spreads with the wind and blankets large areas, destroying vegetation and causing respiratory problems when inhaled. The dust from processing plants can be collected, but the necessary systems are...
costly and not used regularly in Asian plants.

Purification of the graphite powder can be done via different processes. The cheapest and most commonly used process in China is to wash the graphite with acids. The waste products contain pollutants including hydrofluoric acid, mercury and heavy metals which often leak into the environment [5].

**Controversies Outside of China**

In Bengaluru, India, a graphite plant owned by Graphite India is blamed for causing a huge increase in the levels of particulate pollutants in the city’s air. There has been citizen action since the mid 1997 and in July 2012, state officials ordered the plant to seize operations. The decision was appealed about a year later. At the time of writing the plant is still operating and contributing to the pollution issues in Bangalore [6, 7, 8]. The issue has not gotten any attention from international media.

**Coverage of the Chinese Industry**

Graphite is one of the materials covered in the Washington Post’s article series on the effects of lithium ion battery production. They tell the story of several villagers who live near graphite plants. They struggle with the pollution from the plants that in some cases has destroyed their crops and made their water undrinkable. The villagers where often intimidated to stay silent or their complaints where handled by local officials who are more concerned with staying on good terms with a large local employer than helping them. The Washington Post also approached battery producers and consumer product manufacturers for comments on what they are doing to reduce negative impact from their business [5].

Chinese state media has also reported on the pollution caused by the graphite mining industry [9]. The irony in the fact that the pollution caused by the graphite industry in China is largely caused by the demand from growing green technologies such as electric vehicles, is discussed in many different forums and media outlets.

**Initiatives**

The Chinese government has recently introduced new legislation and started cracking down on illegal and excessively polluting graphite mining operations. In 2012 they introduced stricter environmental legislation [9] and in 2018 they will introduce a pollution tax that can be used to control the graphite industry [10].

**Outlook**

**Demand**

In the European Commissions report on critical materials from 2012 they anticipate a 3.5% yearly increase in global demand for natural graphite [2]. With the announcement of Tesla’s battery gigafactory and the growth in the electric and hybrid vehicle markets, it is likely that the demand for high quality flake graphite will increase much more than that. Some experts believe that the demand will more than double over a 10 year period [4]. There are several emerging technologies that could increase graphite demand. These include graphene, pebble bed nuclear reactors, vanadium redox batteries and fuel cells.

**Supply**

Due to China’s increasing measures against pollution it is unlikely that their production of natural graphite will increase over the next couple of years, especially since the synthetic graphite production will probably rise because of practical reasons. The increasing demand might raise the price enough to make new mining projects in the primarily in the Americas possible. There is also the possibility that new purification techniques will lead to a small increase in the supply of high grade natural graphite. It is likely that the increasing demand will have to be filled by synthetic graphite.

**Attention**

For as long as graphite demand for consumer products continue to grow and pollution issues from natural graphite production persist, it is likely that the attention around natural graphite production will continue to grow. Apple has stated that they have switched to synthetic graphite for their current products because of the controversies around natural graphite [5]. If attention grows further some other brand dependent companies are sure to follow suit. The production of synthetic graphite is extremely energy intensive and the case could be made that the switch to synthetic graphite might even be unfavorable to the environment.

**References**


6. Lead

Introduction
Lead is a heavy metal who is considered to be very controversial due to its toxicity. It is on Greenpeace’s list of materials most hazardous to the environment [1]. As the world moves towards energy sources free from fossil fuels, lead might become more important because of its use in energy storage.

Usage
Lead’s largest area of use is in lead-acid batteries, making up 80% of the total usage. Lead batteries are common because they are cheap and stable [2]. In Figure 6.1 the usage of lead is presented. In Figure 6.1 the sizes of lead using sectors are presented.

Production
The main ore that lead is extruded from is called galena. Galena consists of sulfide and theoretically 86.6% lead [4]. The largest producer of lead in the world is China which has over 40% of the world’s lead mines [5].

<table>
<thead>
<tr>
<th></th>
<th>50 %</th>
<th>10 %</th>
<th>7 %</th>
<th>6 %</th>
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</thead>
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<td>Mexico</td>
<td>Australia</td>
<td>USA</td>
<td>Peru</td>
</tr>
<tr>
<td>China</td>
<td>50%</td>
<td>Mexico</td>
<td>5%</td>
<td>7%</td>
</tr>
<tr>
<td>Australia</td>
<td>10%</td>
<td>Russia</td>
<td>5%</td>
<td>6%</td>
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<tr>
<td>USA</td>
<td>7%</td>
<td>India</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Peru</td>
<td>6%</td>
<td>Others</td>
<td>12%</td>
<td></td>
</tr>
</tbody>
</table>

Issues

China
In August 2016, 26 mines were shut down in Hunan, China. The mines are expected to increase their workers safety as well as deal with environmental issues. Heavy metal concentrations in the soil of central Hunan was found [7] and the levels were more than 1,500 over the accepted value. The health risks with using lead is potential damage on the nervous system, which at worst leads to death.

Peru
According to National Geographic, Cerro de Pasco in Peru is the most lead-polluted place in the world [8]. The mine is surrounded by abandoned houses and 90% of the local children have very high blood levels of heavy metals including lead. The news articles on claim that the mine is about to “swallow” the whole city [9].

Attention & Initiatives
The mine in Mont Isa, Australia, has had a very high heavy metal pollution, due to its lead mine. The mining company Glencore has since 2003, improved environmental risks for workers and close by citizens by requesting regular health examinations of the children and stricter measurements [10, 11].
Outlook

According to the International Lead Association, lead is the world’s most recycled metal and their batteries are the most recycled consumer product [12]. Lead from galena is often a by-product from zinc-mining (see page 37) [4]. Due to limitations of zinc mines in Canada, Peru and Australia, lead is expected to increase by 18% in price the upcoming year [13]. Due to the controversy around the mining in Cerro de Pasco, it is important to take caution when importing from this area. Overall, due to its toxicity, lead should be used with caution and can sometimes be replaced. According to the USGS [6], lead can be replaced by plastics when used as cable covers or cans. Also, there is a trend in the weapon industry to phase out lead in ammunition [14]. The world is moving towards lead-free electronics and substitutes to lead-batteries are welcomed.

References

7. Lithium

Introduction

Usage
Lithium has a lot of technical applications. The largest and most commonly known application is lithium-ion batteries, covering 39% of the global use. The demand for lithium ion-batteries is rising rapidly, mainly because of the increasing need for lithium-ion batteries for electric tools and vehicles, and for grid storage applications [1]. The areas of use are presented in Figure 7.1.

![Figure 7.1: Areas of use in 2016 [1]](image)

Production
Lithium can be extracted mainly in two ways. Either, it can be mined from various hard rock minerals, where Australia is by far the world’s largest producer, followed by China, Zimbabwe, Portugal and Brazil. Lithium can also be extracted from brines containing lithium carbonate. This extraction is concentrated to Chile and Argentina, or more specifically what is called the lithium triangle, also including Bolivia [1]. These three countries together hold a huge part of the world’s reserves of lithium, but thus far mining has been far less extensive in Bolivia, much due to a less secure environment for investors [2].

In the Atacama desert, inside the lithium triangle, the brine with the highest-grade lithium has been found [3]. The Atacama desert covers the border between Chile and Argentina, and on the Chilean side, lithium has been mined since the 1980s. Over the last years, the mining has increased on the Argentinean side as well, a lot thanks to president Mauricio Mauri’s moves towards a easier climate for investors [2]. This is discussed further in the section about silver.

The top producers are presented in table 7.1 and the overall world production is illustrated in figure 7.2.

<table>
<thead>
<tr>
<th>Country</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>40%</td>
</tr>
<tr>
<td>Chile</td>
<td>34%</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>16%</td>
</tr>
<tr>
<td>Argentina</td>
<td>8%</td>
</tr>
<tr>
<td>Others</td>
<td>8%</td>
</tr>
</tbody>
</table>

![Figure 7.2: Map of world production in 2016 [1]](image)

Issues
An article in The Washington Post [4], tells the story of two men who visited six indigenous communities in the Argentinean part of the Atacama desert, and describes the ethical complications associated with lithium mining in the area.

Water Usage
The extraction and the refining of lithium is a process that requires huge amounts of water, 1 800 tonnes of water is needed to refine one ton of lithium. In the Atacama desert, the amount of freshwater is limited. The annual rainfall is less than 4 inches and the area has suffered from drought. In the article it says that one of the communities, Pastos Chicos, needed to have fresh water trucked in at the time of the visit. Carlos Guzman, living in Pastos Chicos, says “They are taking everything away from us. [...] We live by this. By the fields. By our cattle. This way of life is in danger.” Carlos Quispe also lives in Pastos Chicos. He made a deal with one of the mining companies, giving them permission to extract lithium in the area. Quispe means that at the time of the agreement, it was not clarified just how much lithium was going to be extracted, and he feels that he would now want a larger compensation.

Aside from facing drought, the communities struggle to finance sewage systems and heating for schools, a difficult
problem in the cold climate at nearly 13,000 feet above sea level. The economical compensation to the indigenous communities is small. One mining company, who made a deal with all six communities, pay the communities between 9,000 and 60,000 dollars a year for the rights to extract lithium from their land, and to use their fresh water during the refining process. Their expected annual profit is approximately 250 million dollars.

One factor contributing to the massive difference in profit is that in Argentina, the provincial governments own the right to the minerals, but the mining companies still need permission from the landowner in order to start digging. The international standard for making deals with indigenous people says that “the people concerned shall wherever possible participate in the benefits of such activities, and shall receive fair compensation for any damages which they may sustain as a result of such activities”. This standard was adopted by Argentina in 2000, but since there is no well defined process for this negotiation, the economical compensation is still not what many would describe as fair [4].

Sacred Land
Another issue related to mining in this region is something that can not be valued by money. To the indigenous people living here, the land is sacred. Nelda Lamas lives in the area, and she says that “Our grandparents taught us that this is a sacred place. It’s part of the Pachamama. [...] that’s why we don’t want to see this place destroyed”. The Pachamama is the Incan goddess of earth [4].

Attention & Initiatives
The primary resistance against the mining comes from the people, but they have received some help from NGO:s. Already in 2011, the International Commission of Jurists (hereinafter referred to as ICJ) helped them to draw attention from the United Nations, where both the UN Committee on Economic, Social and Cultural Rights and the UN Special Rapporteur on the rights of indigenous peoples have given recommendations to the State of Argentina to respect the rights of the communities in the area [5].

Outlook
Argentina
It is unclear what effect ICJ’s actions have had on the indigenous peoples’ influence. This can be related to the fact that the guidelines in the standard for making deals with indigenous people are diffuse. The two parties may have different opinions about the definition of a fair compensation. Furthermore, exacerbating the existing water shortage in the area is hard to compensate financially, not to mention the difficulty of a fair economic compensation for the destruction of their sacred land. This is a perfect example of when regulations are followed legally, but controversies remain, and is of course reason to be very cautious. As these issues become more well known, it is possible that stricter guidelines will be implemented.

Another difficulty is that the lithium mining creates job opportunities and financial profit for some, but cause fear for others, something that has lead to demonstrations. The Washington Post article [4] mentions one case where the woman who made the deal allowing mining companies to begin the mining, made it with personal interest, and that many in the community is now angry about her decision. Since this is an argument inside the community, this is difficult to avoid and to control from the outside. Again, there are no legal disputes around the negotiation, but nonetheless, the deal has resulted in discomfort inside the community. This points to the importance of being aware of the general relation to mining activity in the area.

Bolivia
Bolivia’s Salar de Uyuńi contains the world’s largest single deposit of lithium. Of course, this has led to interest around extracting lithium here, but not much has happened and there are several reasons to why. First, the infrastructure near the saltflats are suboptimal, and a large investment would be required for large-scale mining to be made possible. On top of that, foreign mining companies face heavy taxes, meaning they would lose a large part of the profit. However, the situation may change in the 2019 election [2]. If Argentina’s recent moves towards a larger mining sector proves profitable, Bolivia might want to follow.

Predicted Demand
The demand for lithium is expected to rise in the close future, a lot thanks to the advance of the electric vehicle industry. According to Albemarle, one of the world’s largest producers, the demand is expected to rise with 30,000 tonnes a year, reaching a global consumption of more than 300,000 tonnes by 2021 [6]. Lithium resources are above 25 million tonnes only in the lithium triangle, and with Australia, China and USA sitting on deposits of millions of tonnes as well, the availability is secure in the close future [1]. Some predict that the electrical vehicle industry will grow immensely, and this may lead to problems with availability further ahead [7].

References
8. Manganese

Introduction

Usage
Manganese is a strong and brittle metal. Due to its brittleness, manganese doesn’t have any applications in its pure form. Because of its strength and deoxidising characteristics, it is mostly used in the alloy and steel-industry. Regular steel contains approximately 1% of manganese to enhance wear resistance and workability. There is also a manganese steel, which contains around 13% of manganese, and has applications such as railway tracks and safes. Manganese dioxide is also an important substance since it works as a catalyst, fertilizer and is used in ceramics [1].

Production

Table 8.1: Estimated world production in 2016 [3]

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>South Africa</td>
<td>29 %</td>
<td>Ghana</td>
<td>3 %</td>
</tr>
<tr>
<td>China</td>
<td>19 %</td>
<td>Ukraine</td>
<td>2 %</td>
</tr>
<tr>
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<td>16 %</td>
<td>Mexico</td>
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</tr>
<tr>
<td>Gabon</td>
<td>13 %</td>
<td>Malaysia</td>
<td>1 %</td>
</tr>
<tr>
<td>Brazil</td>
<td>7 %</td>
<td>Kazakhstan</td>
<td>1 %</td>
</tr>
<tr>
<td>India</td>
<td>6 %</td>
<td>Others</td>
<td>4 %</td>
</tr>
</tbody>
</table>

In 2016, South Africa was the leading manganese-ore producer, producing 2.5 million tonnes, followed by China, Australia, Gabon and India[3]. See Table 8.1 and Figure 8.

Issues

Health Risks
The major issue for manganese doesn’t seem to be area restricted. Regarding health issues, studies have been made in several countries connecting high manganese exposure to nerve damages in the all stages of handling.

Studies of workers in manganese mines shows that inhalation of high levels of manganese causes damage to the nervous system. The symptoms of high exposure to manganese include anxiety, ataxia, dementia as well as manganism; a parkinson’s like disease, which is also known as manganese poisoning [4]. A series of reports from Gothenburg called ”Arbete och Hälsa” (Work and Health) has pointed out that manganism is a noted problem in Indian mines. Deficiency in hearing is another problem connected to manganese mining in mainly South Africa, but also in India, Sweden, United states etc. due to a loud working environment [5]. However, the hearing loss isn’t restricted for only manganese mining, but occurs for many other mining sites as well.

Researchers has found that the nerve damages depends on how high the manganese dose is, stating that the mineworkers are at the greatest risk of getting symptoms of high manganese exposure. Inhabitants in the vicinity of mines are shown to also be affected. A study in Ukraine examined 683 children living close to active manganese mining sites. The result showed that there was a 120% increase in bone deformities such as bowed legs and abnormal spinal curvature (from 15% in the reference area to 33% in affected area), and that 46% of the children’s mothers had chronic diseases in connection to their pregnancy and/or delivery [6]. Similar bone-abnormalities in connected to high manganese concentration in the environment has also been documented for animals [7].
Pollution

In Mexico, studies in two habilitated areas close to manganese mines were made. The air concentration of manganese were two to three times larger than normal in the area. The risk of cognitive dysfunction in these areas was 12 times higher than normal and could be connected to manganese exposure. However, the test group was also exposed to lead, which is known to have effects on the neurological system as well [8].

The former mentioned Ukrainian study also researched the environmental effects in the surroundings of the mining sites. It could not be concluded that there were higher amounts of manganese in the surrounding environment [7]. Similar studies has been done in Mexico, which concluded that the plants in the nearby environment of the mine did not accumulate manganese to a toxic level [9].

Attention & Initiatives

There are not any NGOs that are addressing this problem at the moment. The Environmental Protection Agency in the United States had some suggestions for guidelines and further research regarding levels of manganese. This is however solely a proposed presentation [10].

The Ukrainian study proceeded with a rehabilitation treatment directly, which gave positive results for the period the study was made [6]. Generally, the will to improve working conditions and surroundings of the mining sites are low. Most of the focus of negative effects of manganese lies in handling in the welding industry.

Outlook

The future demand and price forecast for manganese varies between analysts. The Global Industry Analysts [GIA] anticipates a growing demand for manganese until 2022. In 2016, the total manganese production was 16 million tonnes [3], and according to GIA the market demand would reach approximately 28.2 million tonnes by 2022. This could possibly result in a supply and demand gap in the future. The increased demand emerges because of a trend showing a steady growth for steel, automobile production and electrolytic manganese for green energy [11]. Similarly to GIA, The Indian Bureau of Mines forecasts a possible demand gap before 2020. Calculations on the steel industry shows a increasing demand which could end in problem due to lack of reserves and production [12]. The Indian Bureau also states that the production issue partially lies in the fact that manganese can not be recycled, but is always dependent on new mining. The U.S. Geological Survey accordingly stated that in 2016 “Manganese was recycled incidentally as a constituent of ferrous and nonferrous scrap; however, scrap recovery specifically for manganese was negligible. Manganese is recovered along with iron from steel slag” [3].

The Merchant Research & Consulting Ltd does not foresee a significant gap nor increasing demand for manganese in the future. They state that the increasing economy and steel industry growth slowly decreases, and that market will mostly be dependent on the steel industry [13].

References

9. Nickel

Introduction

Usage
Nickel is a metal used primarily in alloys, especially stainless steel but also in batteries and electroplating. Due to its ability to resist corrosion, good thermal stability as well as its magnetic and conductive properties, nickel has a wide range of use as seen in Figure 9.1. Nickel allergies are quite common, but nickel does not cause any serious health issues in humans. However there are several issues associated with the production of nickel that will be discussed in this chapter.

Production
Nickel is the fifth most common mineral in the earth's crust [2]. The biggest producer of nickel is the Philippines, having over 24% of the global annual production, as seen in Table 9.1 and Figure 9.2.

Table 9.1: Estimated world production in 2016 [3]

<table>
<thead>
<tr>
<th>Country</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philippines</td>
<td>24%</td>
</tr>
<tr>
<td>Russia</td>
<td>12%</td>
</tr>
<tr>
<td>Canada</td>
<td>10%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>6%</td>
</tr>
<tr>
<td>Australia</td>
<td>10%</td>
</tr>
<tr>
<td>New Caledonia</td>
<td>8%</td>
</tr>
<tr>
<td>Brazil</td>
<td>7%</td>
</tr>
<tr>
<td>China</td>
<td>4%</td>
</tr>
<tr>
<td>South Africa</td>
<td>2%</td>
</tr>
<tr>
<td>Others</td>
<td>17%</td>
</tr>
</tbody>
</table>

Issues

Environmental Issues
The Philippines had the highest production of Nickel globally in 2016. In early 2017, 28 mines were closed due to pollution issues leading to halved production of nickel from the Philippines [4, 5].

Dependence on PGM
The Nickel production in South Africa is often a product of PGM mining [6]. Meaning that if the production of platinum group metals (see page 30) shuts down, nickel will stop being mined there.

Harming Biodiversity
According to the WWF, New Caledonia, located east of Australia, have nickel mines that could be harming the biodiversity of the island [7]. The island has a high percentage of endemic species and its mines are thought to harm the environment. The mining in New Caledonia is according to the WWF, one of the biggest threats to the biodiversity on the island [7].

Attention & Initiatives
Larco is a Nickel mining company which according to Greenpeace provides 6-7% of the European market. The company has been known in 2002, to dump ferronickel waste in Greece, damaging the marine life. Consequently, Greenpeace activists has been protesting this by for example demanding the Greek government to implement laws to prohibit the dumping [8].

Outlook
The nickel demand is expected to increase steadily because of nickel's great importance in several growing sectors, as the technology is improving and the new nickel deposits are
discovered [9]. The supply however, is not expected to keep up because of the recent mine closures in the Philippines [10], which is likely to create a supply gap raising the nickel price.

**Indonesia and the Philippines**

In 2014, Indonesia instituted a ban on nickel exports to limit environmental impact of the mining. The country was then the world second leading supplier of nickel ore, close to the Philippines, as seen in Figure 9.3.

![Figure 9.3: Diagram over the Philippines and Indonesia’s yearly production in million tons [3]](image)

Figure 9.3: Diagram over the Philippines and Indonesia’s yearly production in million tons [3]

The recent years have been very weak for the nickel industry. Due to the recent problems in Indonesia and now the Philippines, the future is looking unstable. In January 2017 the ban in Indonesia was revoked and in May the exports resumed. This might help to offset the decrease in production from the Philippines [11, 12].

**References**


CHAPTER 10. PLATINUM-GROUP METALS

INTRODUCTION

Platinum-group metals (or PGMs) include, apart from platinum; iridium, osmium, palladium, rhodium and ruthenium. PGMs are grouped together mainly because they are chemically similar and occur together in mineral deposits. Except from being mined primarily, they are byproducts from nickel and copper production [1].

The PGMs have excellent catalytic ability. The main use for PGMs in general is catalytic converters, mostly in the automobile industry. Other characteristics that are being utilized are stable electronic and high-temperature properties. For platinum, good wear resistance is a wanted property [2].

USAGE

In 2014, catalytic converters was the largest area of use for Palladium, Platinum and Rhodium, while electronics and electrical applications was the most common use for Ruthenium and Iridium [1]. Figure 10.1 is an illustration of the usage of PGMs in general.

PRODUCTION

In 2014, Palladium was the most produced PGM at 193 tons, followed by Platinum at 146. Russia was the largest producer of Palladium, with South Africa not far behind. For platinum, South Africa dominated the production [2]. The overall top producers of PGMs in 2014 are presented in Table 10.1 and in Figure 10.2.

Table 10.1: World production in 2014 [2]

<table>
<thead>
<tr>
<th>Country</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africa</td>
<td>48</td>
</tr>
<tr>
<td>Russia</td>
<td>30</td>
</tr>
<tr>
<td>USA</td>
<td>4</td>
</tr>
<tr>
<td>Canada</td>
<td>7</td>
</tr>
<tr>
<td>Others</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 10.2: Map of world production in 2014

ISSUES

SAFETY & STRIKES

When considering the two major producing countries, most problems have arose in South Africa, where the unsafe condition in many of the mines are commonly known. A couple of terrible stories can be told from the past years, including an explosion taking fourteen lives in 2014 and an accident in 2009 when falling rocks killed nine miners [3].

In 2014, more than 70 000 South African miners, working on the three main platinum mining companies in the country, went on strike. The reason behind the strike was that the miners considered the salaries to be disproportional to the level of risk associated with the mining. The strike lasted for five months - the longest strike in the country’s history [1]. Two years earlier, strikes in the area around Rustenburg went completely out of hand. Violent clashes between the miners and the police resulted in the death of at least 40 people [4].

ENVIRONMENT & HEALTH

The extraction and refining of PGMs is pretty hard on the local environment. When the ore is taken above ground, it has to be floated and dried. These processes are highly water consuming; on average 400 m$^3$ of water is needed per kg PGM. The smelting and the refining is contributing to air pollution, by emitting dust and SO$_2$. SO$_2$ have...
negative effects on the respiratory functions in the body and may worsen existing problems with the cardiovascular system [5]. These issues - together with large volumes of solid waste - are of course apparent wherever the PGMs are mined, but may be an especially delicate issue in South Africa, a country with limited water resources.

One way of measuring a country’s water supply is to evaluate the amount of renewable water resource per person. Table 10.2 shows the global average and limits for when a country should be regarded as “water stressed” and “water scarce”. In South Africa, the renewable water resource is 1 048 m$^3$ per person and year, meaning that South Africa qualifies as water stressed, on the border to water scarce [6]. This is a clear indication that water-consuming mining processes in the country may bring forth debates, even though the vast water consumption has been noticed by the government and there are restrictions for how much water a mining company is eligible to use [7].

Table 10.2: Renewable water resource per person and year [6]

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Global average</td>
<td>8 210 m$^3$ %</td>
</tr>
<tr>
<td>Water stressed</td>
<td>≤ 1 700 m$^3$ %</td>
</tr>
<tr>
<td>Water scarce</td>
<td>≤ 1 100 m$^3$ %</td>
</tr>
</tbody>
</table>

### Decreasing Profits

Unfortunately, the water-use restrictions have been contributing to other problems for the mining sector. South Africa holds about 80% of the world’s resources of platinum. This is of course a good reason to station platinum mining in the country, and the mining plays an important part for the land’s economy. The problem is that the limited water availability, together with the fact that the global demand for platinum is sinking, have made many mines less profitable. The production has been outweighing the demand, causing the platinum prices to drop, and the future for platinum mining in South Africa is now uncertain [8]. There have already been discussions about poor conditions in some mining communities and some mining companies have been questioned for not taking responsibility in sharing the profits from the mining with the communities from where they extract the ores [4].

### Attention & Initiatives

Multiple NGOs have criticized the dangerous working conditions. In 2016, the National Union of Miners and the Bench Marks Foundation (hereinafter referred to as NUM and BMF), among many others, raised attention about the miners’ safety after an underground fire in a mine near Rustenburg that resulted in the death of four people. According to the NGOs, the accident could have been prevented had the safety standards been better. The NGOs pointed out that the conditions in some mines are a huge risk for the miners safety and health, and urged for improvements [3].

The poor state of mining communities, especially in the Rustenburg area, has also drawn attention from NGOs. Already in 2012, BMF questioned the mining companies’ willingness to improve the situation. BMF meant that despite over 80 years of mining, the communities had seen little of the wealth from the mining. Even though their report found support from NUM, it was by many companies dismissed as misleading. The mining companies meant that the report gave an unfair view of the situation, and that the responsibility for increasing the poor state of the communities should not solely lay on them [4].

### Forecast

As a brief summary, the Rustenburg area has a history stained with unrest, and the future seems to be uncertain. A less profitable mining could aggravate the situation in poor communities, leaving communities impoverished. The uncertain outlook is of course reason to be cautious, as there is no telling how different parties will proceed in order to retain profits. The situation could, over time, cause even more discontent among miners and at its worst, result in new conflicts that could be fatal for the future of PGM mining in South Africa.

### References

11. REEs & Scandium

Introduction
Rare earth elements is a group of 16 elements with similar chemical properties. The group includes the 15 lanthanides and Yttrium. Promethium does not occur in nature and is not discussed further in this report. REEs are often divided into light REEs: lanthanum, cerium, praseodymium, neodymium; and heavy REEs: samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium. The groups differ greatly in usage, availability and in what kind of deposits they are mined from. Scandium is sometimes considered an REE and will be discussed briefly at the end of this chapter.

Usage
REEs have many technical applications. Their use in high performance magnets is especially important. This sector uses large amounts of REEs and is growing rapidly because of the increasing demand from renewable energy and electric transportation sectors.

Light REEs are used in a variety of applications. Lanthanum’s and cerium’s largest areas of use are as a catalyst as a fluid cracking catalyst and in polishing powders respectively. The two of them are also used in large quantities in nickel metal hydride batteries, metallurgy (steel-, aluminum- and magnesium-alloys), glass additives, phosphors and catalysts. Praseodymium and neodymium are mostly used in NdFeB-magnets but they both have several minor areas of use [1].

Heavy REEs are used in much smaller quantities than the light REEs. Samarium, gadolinium, terbium and dysprosium are used in magnets. Europium, gadolinium, terbium, erbium and yttrium are used in phosphors. Gadolinium is also used in metallurgy, erbium in glass additives and yttrium in ceramics. Holmium, thulium, ytterbium and lutetium are all very rare and are not used in large quantities [1].

Production
The REEs are commonly occurring in nature but they are quite evenly distributed across the earth’s crust and notoriously hard to purify and separate. These factors make deposits that are economically viable to mine very rare. REE ores always contain a mix of several REEs. The concentration of individual elements varies greatly across different ores and deposits. REEs are as good as always mined in conjunction with other minerals such as iron or uranium.

Detailed and up to date production statistics on REEs are hard to come by since the market has changed a lot over the last five years. Global per country statistics for total REE production from United States Geological Survey are available in Table 11. These do however not account for the substantial illegal mining in China that is estimated to constitute an additional 40% to the reported Chinese production [2].

Table 11.1: Estimated world production in 2016 [3]

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>84%</td>
</tr>
<tr>
<td>Russia</td>
<td>2%</td>
</tr>
<tr>
<td>Brazil</td>
<td>1%</td>
</tr>
<tr>
<td>Australia</td>
<td>11%</td>
</tr>
<tr>
<td>India</td>
<td>1%</td>
</tr>
<tr>
<td>Others</td>
<td>1%</td>
</tr>
</tbody>
</table>

The newest publicly available per element global production statistics are from 2012. In 2012 circa 10-15% of each of the light REEs was produced outside of China, in the USA, Australia, Russia or India. The global market
has changed a lot since 2012. In late 2015, Mountain Pass, the only mine in the USA shut down operations because of profitability issues. Australia has scaled up their production substantially and deposits of primarily neodymium has been discovered and begun to be mined in Brazil. In 2012, China had 98% of the global production of heavy REEs. Since 2012 no new heavy REE mines outside of China have begun production. There are several projects in Australia, Canada and Greenland that could start production in within a few years, but in the current market climate it is unlikely that they would be turning a profit.

### Issues

REEs are mined from many different types of ores. What they all have in common is that the REE concentrations are low and require complicated separation processes. Because of this, REE mines have relatively large footprints and REE processing generates large amount of waste. Additionally most of the hard rock minerals that are mined for REEs contain radioactive isotopes of thorium and uranium, though the concentration varies greatly between sites [4].

Ionic adsorption clays are source of highly concentrated REEs that compared to hard rock minerals. Ionic clays are used for extraction in southern China either by conventional mining or a technique called in-situ leaching. Conventional mining and processing of ionic clays produce 2000 tons of toxic tailings and 1000 tons of wastewater per ton of rare earth oxides produced. In-situ leaching is less efficient but does not produce tailings. It does however cause severe environmental degradation and is believed to cause landslides. Illegal mining of ionic clays is common in southern China. This is problematic because their impact cannot be controlled through environmental regulation [2].

### Controversies Outside of China

The REE extraction industry has caused two notable controversial incidents outside of China. The first was during the 80’s and 90’s in Perak, Malaysia at the location Asia Rare Earth’s processing plant and dumps of radioactive waste. Locals claimed that the plant had adverse health effects which sparked massive protests and a lawsuit against the company. [5]

The second was during the 90’s at Mountain Pass REE mine, USA, where waste water had leaked from the plant. This lead to a lawsuit and the closure of the mine until it was later reopened under a new administration [6]. These incidents have undermined the publics trust in the industry. This was apparent in the protests against the Lynas advanced materials plant that opened in Malaysia in 2012. Investigation has shown that the plant should pose no health risk to locals inhabitants, but has despite that been met with massive protests [7].

### Coverage of the Chinese Industry

The environmental and public health issues around the worlds largest rare earth mine, Bayan Obo, has been studied academically since the mid 90’s but has not gained attention from international media until quite recently. In 2012, the French newspaper Le Monde and the Guardian both reported on the environmental destruction and social consequences of the mine. Since then, both the Guardian and the BBC has published several articles on the issues. The social and environmental consequences of rare earth mining in other parts of China, for instance the environmental damage from the extensive illegal mining of ionic clays, have not gotten any particular attention from large international media outlets.

### Initiatives

The Chinese government have introduced several measures to control the impact of rare earth mining. In 2010, they introduced export quotas. They have also introduced stricter environmental regulation and are working to reorganize their mining industry [8]. This is a step in the right direction, but far from a solution to the industry’s issues. The stricter regulation also caused a large increase in illegal rare earth mining that the government is struggling to control. There are no initiatives from NGOs that have to do with the rare earth industry in general, but there is more often than not strong public opposition against the opening of new mines and construction of processing plants.

### Outlook

### Shortages

Data published by Roskill Information Services in 2013 predicted a shortage of primarily heavy REEs used in phosphors including europium, terbium and yttrium [1]. Since then there has been a large drop in REE demand in the phosphor market as a result of a shift toward LED technology. That leaves high performance magnets as the market where the most severe under supply is expected [9]. The REEs primarily used in high performance magnets are neodymium and dysprosium.

The mining of ionic clays in China is largely done illegally and is currently responsible for a large part of the global production of yttrium and neodymium. If this production was to decrease it could lead to a severe shortage of these two REEs. The ionic clay deposits are quite limited making up 2.9% of the deposits found in China, but the production from them amounts to more than 35% of the current Chinese production. [4] The production from ionic clays is bound to decrease some time, either because of the
closure of illegal mines or simply because the deposits will be exhausted. When this will happen is unclear.

**Markets**

China has around 50% of the world’s REE deposits and 90% of the current global production. The poor environmental performance means that China produce REEs very cheaply, and that in turn makes it hard for other countries to enter the market. The export quotas introduced by China in 2010 gave rise to a spike in REE prices, allowing other countries to increase production. The world trade organization ruled the quotas illegal in 2016 again increasing Chinese exports and lowering prices [10].

There are many REE mining projects outside of China that are poised to start production, but unless Chinese exports decrease it is unlikely that they will be economically viable for the next few years.

**Attention**

Given the attention the rare earth industry has gotten from media recently there is a possibility that REEs will shortly be controversial in the eyes of the wider public. This might result in pressure on companies to decrease use or source more responsibly, similarly to what has happened to battery materials such as cobalt and graphite recently.

However, for as long as China has such a strong grasp on the market, one can not realistically expect any meaningful change to be made by companies or consumers. REEs are irreplaceable in many of their applications and the Chinese government have already shown that regulating its REE industry is very hard. Sourcing from other countries is not possible if there is no price competitive production that can keep up with the demand.

**Scandium**

Scandium is sometimes considered an REE, but in this article it is discussed separately in brief.

It is extracted from waste from other mineral production. Scandium is only used in very small volumes primarily in high performance aluminum alloys, but also in hydrogen fuel cells and phosphors. It is possible to produce more scandium from existing waste materials, but since the cost to benefit ratio for its use in its major applications is low, so is the demand [11].

**References**


12. Silver

Introduction

Usage
Silver is used widely in electronics, much thanks to its good conductivity. One large industrial application is electrical switches, but silver is also used in superconductors, photovoltaic cells and LEDs [1]. Other sought-after properties are high ductility and reflectivity [2], the later making silver very desirable for decorative purposes such as jewelry. Figure 12.1 shows the overall usage of silver in 2016.

Figure 12.1: Areas of use in 2016 [3]

Production
Silver is mined all over the world. In 2014, The United States Geological Survey listed 19 countries with a production at least 100 metric tons over the last year, and many more producing smaller volumes, including countries from all continents [4]. Since 2012, the annual world production has been above 25 000 metric tons, reaching an all-time peak of 27 000 tons in 2016 [5]. Except from being mined as the primary product, silver is a by-product from lead and zinc mining. Table 12.1 shows the largest producers in the world as of 2015 and Figure 12.2 is a picture of the overall world production.

Table 12.1: World production in 2015 [3]

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico</td>
<td>21%</td>
</tr>
<tr>
<td>Peru</td>
<td>15%</td>
</tr>
<tr>
<td>China</td>
<td>12%</td>
</tr>
<tr>
<td>Russia</td>
<td>6%</td>
</tr>
<tr>
<td>Australia</td>
<td>6%</td>
</tr>
<tr>
<td>Others</td>
<td>40%</td>
</tr>
</tbody>
</table>

Figure 12.2: Map of world production in 2016 [2]

Issues

Child Labor in Bolivia
In the List of Goods Produced by Child Labor or Forced Labor, the United States Department of Labor lists Bolivia as the only country where child labor is currently occurring associated with silver production [6].

The Mountain that Eats Men
In Bolivia, near the city of Potosí, lies Cerro Rico, often called ‘The mountain that eats men’ due to the many people who have lost their lives in the mines. According to the local widows association, 14 women are widowed each month on average, because of the unsafe conditions in the mines [7]. The main reason why many still decide to work in the mines is the potential for economic benefit. If you are lucky, you can make a lot of money in a short time. However, this is solely a matter of luck, and there are no guarantees as to how much you will make [8].

Furthermore, the uncontrolled mining has caused part of the summit to collapse. There are concerns that further mining could destroy more of the mountain, thus ruining prospects for the growing tourism industry in the region which has the possibility to provide prosperity in the area when the mineral resources are exhausted [9]. This is of course yet another reason for it not to be destroyed.

Violence in Mexico
There has been some reports of mining companies using violence, murders in some cases, to silence protests against the silver mining in the area around José del Progreso and in Chihuahua [10, 11].
Attention & Initiatives
Cerro Rico in Bolivia has been a UNESCO World Heritage site since 1987 and in 2014 they added Cerro Rico to their list of World Heritage in Danger [12]. Their advice was for mining to stop completely above 4 400 meters. However, there are indications that these guidelines have not been followed [7].

In 2012, multiple NGOs supported a demonstration in Mexico City, following the murder of the indigenous leader Bernardo Vásquez Sánchez. The purpose of the demonstration was partly to ensure a full investigation on the murder of Vásquez, but also to increase the influence of indigenous communities when negotiations with mining companies, something that Vásquez fought for [13]. Furthermore, three big mining companies in Mexico have gotten critique for jeopardizing local water supplies [10].

Outlook
Taking a glimpse into the future, Argentina is getting ready to develop their mining sector in the coming years. President Mauricio Macri is keen to catch up with the neighbors Chile & Peru, whose mining has generated significantly more profit than Argentina’s in recent years. Macri has an ambition to double the investment in the mining sector in 8 years, and has taken steps towards more attractive standards for the mining companies during his early days as a president. For instance, he has revoked the former tax on mining, and has also removed a prohibition for moving profits made by foreign mining companies out of the country. In addition, Argentina is about to pass a law with a purpose to provide a more stable climate for investors and to avoid conflicts with local communities. However, according to BMI Research, local opposition might arise, and they state that these kinds of conflicts may end up hurting Argentina’s attractiveness for future mining investments [14].

The Department of Labor lists Mexico, the world’s largest producer of silver, as a country with existing problems regarding child labor [6]. In Mexico, there are no signs of child labor directly connected to silver mining but regardless of that, this is still something to keep in mind when purchasing silver sourced from Mexico.

Otherwise, when looking at the largest producers, Peru, Russia and Australia all seem to have a good history of silver mining. However, there are issues around gold mining in Peru that are important to be aware of. An article in the Guardian suggests that a large part of the gold mining in Peru is controlled by organized crime groups, causing environmental damage and human rights abuse. A report by the Global Initiative Against Transnational Organized Crime estimates that 28% of the gold mining in Peru is illegal [15]. The magnitude of this issue is of course reason to be cautious when sourcing any metal or mineral from Peru.

References
13. Zinc

**Introduction**

Zinc is a silvery metal that is the 24th most abundant element in the earth's crust. It is an important element for normal body function; a healthy human body contains 1.4 to 2.3 g of zinc [1]. Apart from being a biological building block, Zinc has many applications in the industry. Zinc is mainly used in galvanization, but has applications as an primary component of structural alloys and for brass, see figure 13.1.

**Usage**

Zinc is mined from sulfide ores, mainly Zinc blende [3]. The extracted sulfides contain other metals as well, such as lead, cadmium, iron and silver. In 2016, China was the main producer of zinc; having 38% of the total production, followed by Peru, Australia, Unites States and Mexico. For production by country in 2016, see table 13.1 and figure 13.2 [4].

![Figure 13.1: Areas of use in 2014 [2]](image)

**Production**

![Figure 13.2: Map of world production in 2016 [4]](image)

**Issues**

**Health Risks**

Several studies regarding environmental and health risks in connection to zinc mining in China have been published. These reports discusses lead-zinc mines, not only zinc mines. They conclude that zinc, lead and cadmium are released into the surrounding environment, polluting soil and crops, thus posing health risks to humans.

Even though zinc is an important element for plants as well as humans, large amounts of zinc can cause health problems. A zinc level exceeding 10-15 times normal can cause nausea, stomach cramps and vomiting. Inhalation of zinc can also cause “metal fume fever”, giving symptoms similar to the flu such as headache, chills and fever [5].

**Pollution**

Soil samples taken in proximity of zinc mines was noted to have an impaired microbacterial culture and lower nutrient levels, making the soil inappropriate for agriculture and affecting plant growth [6, 7]. An article researching several different mining areas in China stated that crops were polluted by tailings and wastewater. It also concluded that water close to the mines accumulated cadmium, lead and zinc, and that vegetables grown in the area was noted to contain increased levels lead and cadmium [6]. Another research group studied communities on different distances from one mine in China, stating that the tap water did not contain dangerous levels of heavy metals. Vegetables grown in areas close to the mine had increased levels of Zn and Pb. Indoor air samples were also found to contain pollutants inducing copper, zinc and lead. The distance to the mining area had an significant impact on the heavy metal pollution.
The study also showed that the village closest to the mine exceeded the lead healthy dose limit by 15 times, whilst the two communities further away exceeded the limit by 2 times [7].

Zinc pollution does occur, but in China the main issue is that zinc is mined together with lead, where lead has a much more severe effect on the environment and health compared to zinc.

**Attention & Initiatives**

There are no major non government organizations working with issues in the zinc mining industry specifically. However, there are limitations and restrictions in relation to zinc emissions.

In 2016, the Chinese government ordered that all zinc and lead mines in the Hunan province should be shut down due to environmental and safety concerns. Effective from 2016, 26 mines have been shut down, with the ban stretching to June, 2017 [8]. At this point it is unclear what will happen after that.

**Outlook**

Most of the forecasts predict that the zinc price will most likely increase in the coming years. China, who is the biggest producer of zinc, closed 26 mines in 2016, greatly reducing the zinc supply. Since 2015, at least 12 zinc mines have been closed in Australia, Canada, Ireland, Mexico, USA, Peru, Saudi Arabia and Kazakhstan. During 2018, additional mines are closing down in Namibia, Thailand, Canada and Poland. Some mines have also decreased their production as a result of low zinc prices [9]. The market seems to be turning at the moment. Reports state that zinc prices has increased by 60% in 2016 [10, 11].

The zinc demand is not expected to increase significantly, but because of the closing zinc mines, the price is estimated to rise the coming years [10, 11]. However, there are currently new zinc mining projects underway in Australia, South Africa and Kazakhstan, and expansion of mines are planned in Eritrea, Greenland and Australia [9]. If and when these projects will start production is dependent on the market, but will take at least a couple of years.

Approximately 30% of the zinc production uses recycled raw materials, while 70% comes from mines. The recycling of zinc is expected to increase as a result of improving technologies [12, 13].

**References**

When gathering information about controversial materials, the versatile nature of many issues is rapidly observed. The social controversies include working conditions and salaries but also how native communities are treated and to what degree they are allowed to share the profits of the extractions taking place on ‘their’ ground. When considering environmental problems, pollution and deforestation give rise to many debates. Some issues are difficult to categorize as either social or environmental, for instance water consuming processes carried out in dry areas. The controversies around material extraction is a hot topic, and these issues are highlighted frequently both by news sites and by organizations targeting specific problems.

General Issues
Some of the controversies that are brought up in the report are apparent in association with more than one material, and can therefore be regarded as general issues. This can either be related to the fact that one material is a by-product of another, or that they are mined in an especially problematic area. One example is nickel, which is partly extracted as a by-product from PGM mining. Thus, all issues associated with PGMs could be regarded as issues for nickel as well. The same thing applies for zinc and lead, they are mined together and the problems surrounding them are the same.

Working Conditions
For a couple of materials, dangerous working conditions for the miners have received a lot of attention. This is especially controversial since the safety standards are often low and the equipment is inadequate. The working environment is often a threat both to the miners safety and health. Many mines are hand dug, and in some areas accidents occur frequently. On top of that, many workers inhale dust from the mining that can in some cases cause deadly lung diseases. Something that is especially disturbing is that in many cases, child labor is mentioned along with dangerous conditions. This is the case both for cobalt mining in DRC and silver mining in Bolivia.

Environmental Damage
Different kinds of environmental damage are brought up in the report. The focus has been on consequences on the local environment, so pollutions having a global impact is not included.

As mentioned before, zinc and lead mining are often correlated. Lead is known to be toxic and exposure could lead to severe damage on the nervous system, but large volumes of zinc are pollutive as well. Many zinc and lead mines all over the world have been shut down and in other areas there are restrictions about the operation.

Malaysia has a history of environmental issues associated with their mining. Different kind of mines have been shut down due to environmental damage. In the same area lie Indonesia, whose nickel-production recently opened again after being closed for three years due to environmental impact. Around the same time, the Philippines closed their nickel mines, also because of environmental issues.

Both nickel and chromium mining has been discussed as potentially harmful for biodiversity. A chromium incident in Zimbabwe resulted in polluted seas and there have been concerns about producing nickel in New Caledonia, because of the fact that the country is the home of various endemic species.

Impact on Communities
In India, several issues have surfaced in areas close to large mining sites, where chromium and manganese mining are two examples. Leaks have been causing birth defects and diseases, like manganism (a disease causing dementia). Manganism has been an issue in other countries as well.

In South America, a couple of issues have surfaced where communities nearby mining sites have been exposed to toxic chemicals. In Chile, for instance, a whole town had to be relocated due to contamination of copper. Another problem is that mining can lead to the destruction of crops and pollution of drinking water. This has been highlighted for graphite mining in China.

Something else, that does not have to do with pollution or emissions, is the fact that the rights of native people are not always being followed. This is an issue associated with multiple materials and countries. In some cases, indigenous people have had to leave their home to give place for mining, and in many places native communities are left impoverished after the ores are extracted and the communities are left without a fair compensation. To add to that, many mining processes are highly water consuming, a really vital issue for example in the dry areas of South America.

In some cases, violence has been mentioned as the way to deal with people who are against the mining, causing even more fear and discontent among the opposition.
Illegal Activity
China is the main producer of many materials; zinc, lead and REEs are some examples. Apart from the inevitable large waste piles from the mining, and huge amounts of wastewater, there are several reports of wide-spread illegal mining, associated with REEs to name one. When mining is carried out illegally, regulations are often neglected. One example of this is incorrect dumping of toxic waste which is resulting in polluted rivers.

There have also been reports about violations of human rights connected to multiple Chinese mining companies operating abroad, an issue that has been addressed by Human Rights Watch.

China has implemented strict regulations regarding both REEs and chromium and are expected to deal with both social and environmental issues. However, due to the magnitude of illegal activity, some issues are going to be very hard to overcome. China is far from the only country in this report where illegal mining is mentioned, but because of their huge role in the world’s production, they receive most attention.

Organisations
For each material, some initiatives or campaigns for the specific material are discussed. One organization mentioned in several places in the report is the US Environmental Protection Agency, who have suggested guidelines about levels of aluminium, manganese and zinc, and demanded mandatory reports for when emissions of CO₂ exceed limitations. There are organisations who work with social and environmental issues at a global perspective, of which some are brought up below.

Amnesty
Amnesty is mentioned in the report as they highlighted the issue with child labor and dangerous working conditions in DRC and demanded the operation of a copper mine in Myanmar to stop because of numerous problems regarding violation of human rights. In their International Report, Amnesty brings up the state of human rights in 159 countries and territories. They include different kind of ill-treatment and torture from armed groups, issues regarding sexual rights and government surveillance to mention some. The report gives a good look over the situation in many countries, and is a good way to become aware of different issues. The international report of 2016/17 is available online [1].

Greenpeace
Greenpeace has numerous ongoing campaigns addressing issues regarding climate change, deforestation and pollution of oceans to mention some. They have compiled a list of hazardous materials, which is mentioned in this report (more can be read under lead). Greenpeace work toward large companies - they have for example influenced Nestle and McDonalds - but also governments, and they try to find political solutions to many issues.

Greenpeace are campaigning for a global mechanism known as REDD (reducing emissions from degradation and deforestation). The mass destruction of rainforest around the world does not only effect the biodiversity and contribute to climate change, but also interfere with the rights of forest communities. Greenpeace work to stop oil- and nuclear based energy and encourage the stride for a world with 100% renewable energy.

On their website they list threats and solutions surrounding many issues [2].

OECD
During a meeting with Chris Bayliss, deputy secretary general for the Aluminium Institute, he stated that OECD is currently working on a project similar to this one, including more materials. Their report is preliminary planned to be published later this year (2017).

Outlook
During research for the investigated materials some trends could be distinguished. There is an increasing awareness around the issues that are brought up in this report, and there is a lot of activity going on right now. Due to the complexity of the issues surrounding the materials, this report serves mostly as a pointer as to what issues to be aware of. However, some suggestions to minimize the risks associated with controversial materials are mentioned.

Due Diligence
The Organization for Economic Co-operation and Development (OECD) has a guidance for how a thorough due diligence can be done [3]. This process is recommended by both Amnesty [4] and the United Nations [5], as a way for companies to adhere to good ethical standards.

Increasing Awareness
Generally, the attention for issues regarding material mining and harvesting is increasing, and regulations in connection to this are being developed or have been developed recently. Apart from the organisations discussed earlier such as Amnesty and Greenpeace who work with improving the environment and human rights, these topics occur often on various news sites as well. During the research, several articles was published just a few days earlier, which shows that this is a topic that people are interested in right now.

When it comes to improvement and initiatives, there are relatively new trends towards both stricter regulation of the mining industry and increasing accountability in raw material sourcing. Recently, the members of the European parliament approved new legislation regarding obligations for due diligence, but is solely restricted to conflict minerals. Also, France imposed a law in march 2017, demanding all large companies located in France to perform due diligence on their supply chain for all materials in order to raise awareness and encourage better choices regarding human rights, health and safety, and environmental aspects. The final step is for the law to be accepted by the constitutional court to make the law valid [6].

Recommendations
There is no easy answer for how to tackle these negative effects of the mining industry. Especially since it is rarely
Table 13.2: Overview of the most important issues for each material.

<table>
<thead>
<tr>
<th>Material</th>
<th>Worker Health</th>
<th>Local Health</th>
<th>Biodiversity &amp; Environment</th>
<th>Child Labor</th>
<th>Social Conflicts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cobalt</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithium</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Graphite</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PGMs</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REEs</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silver</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

the case that the end product manufacturer has direct contact with the mining company or workers; the material often goes through several intermediaries before reaching the producer. This complicates the due diligence process since a lot of information gets lost on the way, and it thus becomes easier to fake records. Apart from the producer doing the due diligence process, which is rather complicated, some other suggestions are possible to minimize the risk of sourcing controversial materials.

A possible course of action could be to demand a more detailed account of raw material origin from sub-suppliers. However, the delivery company probably has many intermediaries itself, putting them in the same position as the producer. But, by demanding some sort of security regarding the material, this opens up the issue one step further down the chain. Showing that awareness of controversial materials is of interest for the consumer, could possibly start a chain reaction where the deliverer starts demanding information further down the chain since it is of importance for the customer, and thus in the end possibly affect the conditions further down the chain if there are problems associated with the material.

Another action could be to hire a consultant firm that for example could perform the due diligence, create a template for how to avoid bad ethical decisions or to raise awareness regarding material choices. There are many research institutes performing exactly these sorts of investigations in relation to working conditions as well as environmental impact. For example, the National Research Center Inc helps companies to measure their effectiveness and has specialty surveys researching about environmental issues and community health. Also, Oakdene Hollins is a consultant research firm specialized on sustainability and circular economy.

One option is to design a security template for people working with the materials, both current and possibly new. An example of this has been made at Blekinge Institute of Technology, where a group of people has developed a method for how to cope with critical materials in relation to both the environmental and social aspect. The developed method compares the criticality of different alloys depending on which metals that are used in the alloy. The suggested process is the following for critical materials:

- Firstly, identify the critical materials in the alloy
- Secondly, rank the level of criticality for the alloys
- Lastly, compare the sustainability ranking of alternative alloys

Implementing a custom version of this in the whole company would help to raise awareness and influence material choices.

Awareness of the problems and risks associated with consuming the material is key as well. This report itself has brought this question to the surface, but there are still many aspects that are not brought up. However, there are many online sites and companies that investigates and raises these concerns, as well as works preventative by making estimations of the future. Some examples of this are ChemSec who works with toxic use reduction, and has a so called “SIN-list”, which is a database of hazardous chemicals that are likely to be banned in the future. The European Commission has several reports about materials and their uses, supply and demand as well as issues. They have published two raw material reports, one with critical materials and another with non-critical materials. The Joint Research Center of the European Commission also has one report discussing several critical materials.

These are all possible approaches for how a company can minimize and avoid bad ethical decision. The research and development department can influence material choices and possible actions for how the company should handle the issue, but the final decision lies withing the investment and buyers department since these are the departments handling the procurement of materials.

Summary

To summarize, there is a lot of work going on, trying to overcome different issues. Even though the situation is very complex in many cases, a simplified summation of the problems for each investigated material can be seen in table 13.2, as well as some things can be mentioned regarding what to be cautious about in general.
• Child labor and low safety standards; this is important to be aware of, for example if Bolivia are going to expand their mining sector.
• The development in the area around Malaysia; if there are more issues regarding environmental impact, the mining situation in this area might change.
• Mining activity that results in deforestation or harm on biodiversity in general; for example in Chile, where expansion of mining sites has been up for discussion.
• Mining processes consuming large amounts of water; this is of course most relevant in dry areas, for instance in South America.
• Illegal activity, especially in China; it is difficult to predict whether the illegal mining will increase or decrease, and what consequences it might have.

The future will probably hold a lot of discussion surrounding controversial materials. It will be exciting to see the development in France after their newly inducted law related to due diligence. It is likely that similar regulations will be introduced in other countries, as a result of the rising awareness around production-related issues. Hopefully, this report will contribute to increased awareness around the controversies of material extraction and facilitate the process of future material choices.

References