LAPPEENRANTA–LAHTI UNIVERSITY OF TECHNOLOGY LUT
School of Energy Systems
Department of Environmental Technology
Circular Economy
Master’s thesis 2021

Anni Orola

Social life cycle assessment of cobalt mining in Democratic Republic of Congo

Examiners: Associate professor D. Sc. (Tech.) Ville Uusitalo
Assistant professor D. Soc. Sc. Jarkko Levänen
Instructor(s): Junior Researcher M. Soc. Sc. Anna Härri

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT
School of Energy Systems
Ympäristötekniikan koulutusohjelma
Circular Economy

Anni Orola

Koboltin kaivamisen sosiaalinen elinkaariarviointi Kongon demokraattisessa tasavallassa

Diplomityö

2021

101 sivua, 8 taulukkoa, 12 kuvaa ja 7 liitettä

Työn tarkastajat: Apulaisprofessori TkT (Tech.) Ville Uusitalo
Apulaisprofessori VTT Jarkko Levänen

Työn ohjaaja: Nuorempi tutkija Anna Härri

Hakusanat: Sosiaalinen elinkaariarviointi, Koboltti, Kongon demokraattinen tasavalta

Ilmastonmuutoksen torjunta autokannan sähköistämisen kautta vaatii kasvissa määrin resursseja. Näitä ovat esimerkiksi maametallit, joiden kaivamiseen matalantulotason maissa liittyy sosiaalisen kestävyyden haasteita.

Diplomityön tavoitteena oli selvittää koboltin kaivamisen sosiaalisia kestävyysvaikutuksia Kongon demokraattisessa tasavallassa kirjallisuuskatsauksen ja sosiaalisen elinkaariarvioinnin avulla. Lisäksi tavoitteena oli arvioida sosiaalisen elinkaariarvioinnin käytettävyyttä tutkimusmenetelmänä.

Tietoa kuvailevaa kirjallisuuskatsausta varten kerättiin tieteellisistä julkaisuista, kansainvälisten organisaatioiden raporteista ja haastattelumateriaalista. Sosiaalinen elinkaariarviointi perustui kansainvälisiin standardeihin, ohjeisiin ja versioon QALY menetelmästä.

Tulokset viittaavat siihen, että koboltin kaivamisella on merkittävä negatiivinen vaikutus ihmisten hyvinvointiin Kongon demokraattisessa tasavallassa. Suurimmat vaikutukset liittyivät stressiä ja ahdistusta aiheuttavaan työhön ja sen oheisvaikutuksiin. Sosiaalinen elinkaariarviointi todettiin käyttökelpoiseksi ja helposti viestittäväksi menetelmäksi, vaikka QALY menetelmän yksityiskohtaisempi standardointi olisikin suositeltavaa.

ABSTRACT

Lappeenranta–Lahti University of Technology LUT
LUT School of Energy Systems
Degree Programme in Environmental Technology
Circular Economy

Anni Orola

Social life cycle assessment in Democratic Republic of Congo

Master's thesis

2021

101 pages, 11 tables, 12 figures, 7 appendices

Examiners: Associate professor D. Sc. (Tech.) Ville Uusitalo
Assistant professor D. Soc. Sc. Jarkko Levänen

Supervisor: Junior Researcher M. Soc. Sc. Anna Härri

Keywords: Social life cycle assessment, cobalt, DRC

Mitigation of climate change through sustainable energy transition requires increasing amounts of resources. Serious social sustainability challenges have been linked to earth element extraction in low-income countries.

The aim of this Master's thesis was to perform a literature review and social life cycle assessment to find out and measure the social sustainability impacts of cobalt mining in Democratic Republic of Congo. Another aim was to assess the usability of social life cycle assessment as research method.

Non-systematic literature review was performed utilizing scientific literature, reports of international organizations and interview material. Social life cycle assessment was based on the relevant standards, guidelines and interpretation of QALY methodology.

The results implied that cobalt mining had significant negative impacts on human wellbeing in DR Congo. Largest impacts are linked to stressful working conditions and side effects caused by the anxiety. Social life cycle assessment was evaluated to be a useful and easily communicable method even though there is need to develop standardized methodology.

ACKNOWLEDGEMENTS

I want to thank the examiners and instructor of this master’s thesis for the support and possibility to select such an interesting topic. In addition, I want to thank my family and especially Lauri who has shared co-working space, formerly known as living room, with me. It has been 1,5 years now since were locked in. Also, thank you Krista for the mental support and co-suffering during the last 7 years since this will be the second time we graduate together.

In Lahti 6 August 2021
Anni Orola

TABLE OF CONTENTS

LIST OF SYMBOLS

Abbreviations

EV	Electric vehicle
LCA	Life cycle assessment
SLCA	Social life cycle assessment
ELCA	Environmental life cycle assessment
LCC	Life Cycle Costing
LCSA	Life cycle sustainability assessment
SDG	Sustainable development goal
DRC	Democratic Republic of Congo
ASM	Artisanal and Small-Scale Mining
LSM	Large Scale Mining
LiB	Lithium-ion battery

1 INTRODUCTION

The United Nations Agenda 2030 and Sustainable Development Goals (SDGs) released in 2015 put an emphasis on solving the social, environmental, and economic challenges as one (United Nations 2015). It has been recognized that all the challenges are part of the same system and achieving one sustainability goal can affect the possibility to achieve another (Pradhan et al. 2017).

Climate change, as one of the greatest challenges to all humankind, has caused the need to develop new low-carbon technologies. Electric vehicles are one solution to decarbonize traffic systems. The increasing number of batteries puts pressure on mining industry since the earth elements needed for the current technology are running out. Some of them are predicted to peak during the next two decades. The recycling technologies are not developed enough to economically separate all earth elements for reuse. (Turcheniuk et al. 2018)

Cobalt is one of the elements currently used in electric vehicle (EV) battery manufacturing. It has been recognized as critical material for technological progress by European Union. Cobalt is not rare, but easily exploitable deposits are available only in few countries. (Cobalt Institute 2021) According to International Energy Agency (2020) 19 kt of cobalt was estimated to been used in electric vehicles in 2019. In 2020 the EV cobalt demand was around 39 kt (Desai & Nguen). The annual overall cobalt extraction is between 123-128 kt (van den Brink 2020). It was also estimated that the annual cobalt demand would rise over 370 kt by 2030 if the goals of the Paris Agreements were achieved (International Energy Agency 2020). Until efficient battery recycling technologies are developed the mining industry requires quick expansion.

Expanding mining activity can have serious consequences from health impacts to driving people away from their homes and destruction of their traditional livelihoods (Sovacool 2019; Amnesty International 2016). Social sustainability impacts are linked to cobalt production as well as other earth elements utilized in EV batteries (Thies et al. 2019). International value chains are important to assess since the benefits and trade-offs affect different nations (IPCC 2018). Earth elements are often mined in low-income countries, with less regulation and worse human rights situation than in high-income countries (Amnesty International 2016). It should also be recognized that climate change mitigation benefits most nations that are upstream of the value chain since they are most vulnerable to its effects (IPCC 2018).

Consumers and companies should have a way to compare between products based on their impacts in all dimensions of sustainability. Life cycle assessment (LCA) has become standard for environmentally conscious businesses and academic studies. The methods to apply LCA to social sustainability challenges has been developed and recently gained more and more interest. (Life Cycle Initiative 2020) The social LCA (SLCA) methodology has not been fully established yet and more research and case studies are needed to further its development.

1.1 Objectives and scope

The objective of this study is to gain the methodological knowledge to apply social life cycle assessment in a context of cobalt industry in Democratic Republic of Congo (DRC). Since the social life cycle assessment methodology has not been fully developed yet, the application and utility are assessed in addition.

Following research questions are examined in the thesis:

1. How cobalt life cycle affects on social sustainability?

2. What are the analytical possibilities and challenges of social life cycle assessment in a cobalt case study?

The first research question is answered by conducting literature review and SLCA analysis. The second question is answered based on the perceptions made during SLCA process.

1.2 Structure of the thesis

In the next part of the thesis theoretical framework concerning social sustainability is presented. In the 3rd chapter SLCA methodology and its applications are introduced as well as the literature review and interviews used as base for the assessment. There results of the literature review are described in the 4th chapter. The SLCA is executed in the 5th chapter. The results are presented in the 6th chapter discussed in the 7th chapter. Conclusions are made in the 8th chapter. Summary is given in the 9th chapter.

2 THEORETICAL FRAMEWORK

Sustainability is defined as meeting the needs of today without compromising the future. In addition, it can be thought making decision that does not harm the current life in other part of the globe. It is divided in 3 aspects social, ecological and economic or in other words people, planet and profit. The aspects are also called triple bottom line. (Elkington 1998) Sustainability can be further divided into different indicators e.g., in United Nations sustainable development goals (United Nations 2015).

Economic sustainability concerns economic growth, development, production, and distribution of wealth. Economic sustainability can be measured in paid taxes, community and infrastructure investments, over minimum living wage salary, acts against corruption and cartels or preferring local suppliers and workforce (GRI 2020). Costs and profits are the base for economic indicators. The economic aspect is often visible in both ecological and social sustainability (Shamraiz et al. 2019).

Ecological sustainability is often thought through planetary boundaries concept. Planetary boundaries are limit within the safety of the humankind is ensured. If the planetary boundaries are exceeded there may be catastrophic consequences. The aspects of planetary boundaries are climate change, novel entities, stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, biochemical nitrogen and phosphorus flows, freshwater use, land system change and biosphere integrity. (Stockholm Resilience Centre 2021; Rockström et al. 2009) In business context common indicators are material, energy use and water use, waste generation and emissions (GRI 2020).

Social sustainability includes e.g. human and labour rights, social equity, rights of indigenous people and community development. In business environment it means identifying and managing positive and negative impacts of business activity on people. (United Nations Global Compact 2020) Common indicators used in social sustainability studies are e.g.: occupational health and safety, education, diversity and equal opportunities, discrimination, freedom of association, child labour, human and indigenous rights, customer safety, public policy, marketing and labelling and customer privacy (GRI 2020). In the bottom level the social sustainability is meeting all basic needs of the human life. (Vallance 2011)

Human wellbeing can be difficult to define or measure. Wellbeing can be self-centred or concern larger community since everything that is good for one person may have trade-offs with others. Wellbeing is related to happiness, which makes it partly philosophical challenge. Human wellbeing is often thought as physical and mental health, but the definition may vary depending on context. In addition to health, autonomy and freedom are argued to be linked with wellbeing. (Clark 2014)

One of the most important health research programmes is the global burden of disease study. The global burden of disease has been modelled since 1990s by the WHO (World Health Organization). It estimates mortality and disability caused by different health conditions like diseases and injuries in different countries. As a result, gap between ideal situation and current health status is calculated. The health part of this study is largely based on the foundation of global burden of disease study. Whereas other wellbeing indicators derive from the sustainable development goals, whose significance as a set of wellbeing indicators has been recognized (Clark 2014).

Sustainable development goals which are derived originally from United Nations millennial goals are set of indicators and targets that UN aims at achieving by 2030 (United Nations 2019). These are also referred as grand challenges of sustainability since they are complex problems, which are difficult to solve. Achieving all sustainability goals similarly is considered as a challenge, because of the trade-offs they possess with each other (United Nations 2019). The interconnected nature of sustainability challenges should be recognized in sustainability assessment. Therefore, in addition to environmental metrics new ways to measure social and economic sustainability are developed.

However, measuring impacts in only larger scale is not sufficient since many decisions are made by single corporations and individuals. Social sustainability impacts of a single product are assessed by using social life cycle assessment. The aim of the assessing social sustainability impacts is to make comparison between different products possible. This is enabled by putting sustainability information in numerical metrics and evaluating the seriousness of different actions if the product system is altered. (Life cycle Initiative 2020)

3 METHODS

Literature review was conducted to find out about social challenges and mechanisms related to mining industry in Democratic Republic of Congo (DRC). Unstructured interviews were also utilized. The findings of the review were further studied and quantified in social life cycle assessment.

3.1 Literature review and interviews

Literature review was recognized to be an important way to get full picture of the social situation of DRC and the impacts of mining industry in there to be able to build the social life cycle assessment model. The literature review was non-systematic concentrating on finding critical data for the SLCA model.

The literature review was conducted by searching data concerning social situation and impacts of DRC mining industry from academic databases, human right and other international organizations' publications and international news media. Search words like DRC mining, ASM mining and DRC social impacts were used. In addition, general information about artisanal mining and occupational diseases and injuries were searched to complete the data.

In addition to searched data unpublished primary interview data by Pro Ethical Trade Finland was utilized in this study. The interviews were conducted in 2019. The data contained unstructured interviews of human right organization representatives, political figures, local residents and mine workers in multiple locations in DRC. The results of the interviews are referred as respondent and their respondent number. The list and descriptions of the respondents is presented in appendix 1.

3.2 Social life cycle assessment

Social life cycle assessment was selected as method to assess the social impacts considering different stakeholders. Social life cycle assessment is used as a method in studies concentrating on social sustainability of a system or a product. It can be used in different studies related to business and academic world. The assessment is needed to recognize which life cycle stages have highest impacts to social wellbeing and how the wellbeing can be improved. The human needs and wellbeing related to LCA can be defined for example though the UN SDGs (Kühnen & Hahn 2017).

Social life cycle assessment is based on the ISO 14040 and ISO 14044 standards originally designed for environmental life cycle assessment, which is the most applied form of LCA. Life Cycle Initiative (2020) has published additional guidelines for executing SLCA.

LCA is an iterative process that contains four different phases: goal and scope definition, inventory analysis, impact assessment and interpretation. Goal and scope define the aim, means and criterion of the study. System boundary is defined as well as functional unit. Functional unit is based on the function that the defined system provides e.g. painting one house. Also, data quality required for the study, assumptions made in the calculation and limits concerning impact assessment methods are defined. (Life Cycle Initiative 2020)

Data is collected and the system is modelled in inventory analysis. Results are calculated during the impact assessment by characterizing the inventory data to impact categories. In interpretation phase, the results are assessed to be in line with the goal and scope definition and data uncertainties are studied. (Life Cycle Initiative 2020)

According to Weidema (2019) social impacts can be divided into biophysical and socio-economic impacts. Biophysical impacts are midpoint impacts affecting ecosystem and physical health like acidification, human toxicity or human impacts of global warming. These are similar to Environmental life cycle assessment (ELCA) impact categories. Socio-economic midpoint impact categories include absolute poverty, forced human migration and insufficient skills.

SLCA can study systems from the perspective of different stakeholders. Stakeholder categories are workers, local community, society, consumers, and value chain actors. Different stakeholders are affected on different life cycle phases. Often only workers are included in studies. Following stakeholder subcategories are linked to different stakeholders assessed in this study. (Life cycle initiative 2020)

Worker:

- Freedom of association and collective bargaining
- Child labor
- Fair salary
- Working hours
- Forced labor
- Equal opportunities and discrimination
- Health and safety
- Social benefits and social security
- Employment relationship
- Sexual harassment
- Smallholders including farmers

Local Community:

- Access to material resources
- Access to immaterial resources
- Delocalization and migration
- Cultural heritage
- Respect of indigenous rights
- Community engagement
- Local employment
- Secure living conditions. (Life Cycle Initiative 2020)

The field of SLCA is currently shattered and uniformity is needed. The major challenge considering current SLCA studies is the lack of common indicators, which makes comparison of different studies impossible. (Life Cycle Initiative 2020) One of the main goals of traditional LCA is to enable comparison between different systems or products e.g. environmental product declarations. (Passer et al. 2015) There is also lack of purely theoretical studies since most of the conducted studies have been empirical focusing on company performance. Theoretical research is needed to be able to develop valid SLCA impact pathways. (Kühnen & Hahn 2017)

There are two different main approaches for Social life cycle assessment: reference scale approach and impact pathway approach. Reference scale approach concentrates of social performance or risks of a product or organization putting results on the reference scale from e.g., low to high risk. Impact pathway approach assess impacts of longer time frame and results are calculated on mid-point and endpoint impact categories. In other words, reference scale studies whether any the risk or inequality exist in the value chain, whereas impact pathway studies how social consequences of the system affect on areas of protection e.g., human wellbeing. (Life Cycle Initiative 2020)

Hosseinijou et al. (2014) argue that social impacts are more connected to the company than to the materials and processing methods. The study concentrated on the social hot spot analysis method, which analyses the short time impacts in value chain. This is probably why the life cycle initiative (2020) has developed a separate LCA guideline for the assessment of entire companies. This kind on approach is however difficult to apply in a study that does not involve cooperation with a company.

Impact pathway has several variations in addition to traditional impact pathway. Traditional impact pathway SLCA methodology is very similar to ReCiPe ELCA method in terms of modelling different pathways to one end-point indicator. Preston pathway studies impact pathways by using Preston curve. Preston curve links health and wealth data together and can be used to predict the future and explain the past health effects of a population. Certain criteria have to be met to be able to utilize the Preston pathway. Such criteria are e.g. low corruption and equal wealth share among population (Feschet et al. 2013) Wilkinson pathway is another method that studies income inequality and its causal relationship to health. It is developed based on Preston pathway and Wilkinson curve. (Bocoum et al. 2015)

Impact pathway has been declared to be an open field for future studies (Life Cycle Initiative 2020). The impact indicators and characterization models are not closely established yet. It is an interdisciplinary method that enables systems thinking. Systems thinking is important, when considering social impacts as a part of larger picture like SDGs. (Kühnen & Hahn 2017)

The most developed traditional impact pathway methods are DALY (Disability-Adjusted Life Years), QALY (Quality-Adjusted Life Years), and WELBY (Wellbeing-Adjusted Life Years). These endpoint indicators are health related and DALY and QALY is originally used in medical sciences (Life Cycle Initiative 2020). DALY can be used in LCA context to calculate life lost and spent disabled e.g. due to working conditions or malnutrition (Stein 2007; Arvidsson 2018). QALY takes wider wellbeing perspective into account compared to DALY. (Weidema 2019). DALY has already been used in several LCA studies e.g. Furberg (2018), Stein (2007), Arvidsson (2018), whereas there was no available concerning studies where WELBY or QALY had been used.

WELBY, developed by Weidema (2006), is similar to QALY and it has been proposed to be the most promising method for impact pathway approach. It emphasizes the importance of holistic view in LCA. The challenge with WELBY is that only suggestions to further development of it can be found in the scientific literature. The actual modelling principles and case studies are missing suggesting that it currently exist only in very theoretical level. (Brazier & Tsuchiya 2015)

Weidema (2006) proposed a way to calculate QALY by adding wellbeing factors to calculation. Damage categories according to Weidema (2006) are following:

- Life and longevity (YLL = years of life lost) (Life expectancy)
- Health (YLD)(disability = disease or injury)
- Autonomy (YWL = Years well-being loss)
- Safety, security and tranquility (YWL = Years well-being loss)
- Equal opportunities (YWL = Years well-being loss)

- Participation and influence (YWL = Years well-being loss)

Positive impacts have not been assessed in Weidema's model except for crime victim compensation. Model should be developed to meet the current need to analyze both positive and negative effects.

According to Weidema (2019) human area of protection (AoP) can be defined in wellbeing or lost utility. The endpoint indicators or AoPs are indicators at the end of the impact pathway that do not have interactions with other indicators and are independent. Whereas midpoint indicators can have interactions with other midpoint indicators.

Limitation of QALY is that it often fails to represent worst case scenarios. In addition, it has reported to lack sensitivity. Adding WELBY metrics has been argued to solve the sensitivity issue. (Life Cycle Initiative 2020) the result of WELBY should be assessed with caution since the method is not fully developed. (Schaubroeck & Rugani 2017) WELBY is used as an impact assessment method in this study.

4 COBALT PRODUCTION PROCESS

The results of the literature review are presented in following subchapters. Social impacts are divided according to main life cycle stages. The review concentrates on upstream processes of EV battery manufacturing because most of the sustainability challenges has been recognized to occur there.

4.1 Cobalt value chain

Cobalt is mined in several countries including Democratic Republic of Congo (DRC), Australia, Russia and Finland. DCR has the largest cobalt reserves in the world. Cobalt can be found in different geological forms in different areas. Cobalt and copper often occur together in the same ore in Central Africa. In other parts of the world cobalt often appear together with nickel. (Petavratzi 2019) Large cobalt reserves are also found in the sea beds, but there are currently multiple factors that prevent utilizing them. (van den Brink et al. 2020)

China refines 46 % of all cobalt in the world. Other large cobalt refining countries are Finland, Canada, Belgium, Zambia and Australia (van den Brink et al. 2020). Cobalt originating from DRC is often partly refined in DCR and partly in China (USGS 2021). Cobalt is hydrometallurgically refined in DRC to produce cobalt hydroxide. Cobalt hydroxide is transported to China where it is further refined to cobalt tetroxide and cobalt sulfide. These are used in battery cathode production. (Amnesty International 2017, 37; Crundwell et al. 2020) LiCoO2 (LCO), which is the most common lithium-ion battery (LiB) cathode is produced from cobalt tetroxide (Manthiram 2020).

However, LCO is not the LiB type used in current EVs since it is more suitable for portable electronics. To reduce the amount of cobalt in EV battery Tesla has developed Lithium Nickel Cobalt Aluminum Oxide (NCA) battery whereas other EV manufacturers use Lithium Nickel Manganese Cobalt Oxide (NMC) battery models. Currently the most common NMC battery type is NMC 622. NMC 622 contains nitrogen, manganese, and cobalt in a N6:M2:C2 relation. The average cobalt amount in the NMC 622 battery is 12 kg. NMC 811 battery is already in the development phase reducing the need for cobalt even more. (MCKinsey & Company 2018; Battery University 2019) CoSO4 used in NMC cathode manufacturing can be directly extracted from sulfidic cobalt ore typical to former Katanga region in DRC (Santoro et al. 2019).

Currently there are several efforts to remove cobalt completely from EV batteries. Tesla is working together with their battery suppliers to develop cobalt free EV battery in few years. (Nikkei Asia 2021; Morris 2020) Tesla has already shifted to cobalt free LFP (Lithium iron phosphate) technology in Chinese EV markets (Cleantechnica 2021). The LFP technology has been used in Chinese battery electric busses (Sustainable Bus 2019; Du et al. 2019).

Lithium-ion batteries as final product are typically manufactured in China, Japan, or South Korea. The EV manufacturers are western or Asian as are the consumers benefitting from the products. Three largest EV producers by market share are Tesla (USA), Volkswagen (Germany) and SAIC (China). (Amnesty International 2016, 46; Statista 2021) China has the largest amounts of registered EVs, while the amount of registered EVs has increased the most rapidly in Europe. Total of 3 million new EVs were registered in 2020. (International Energy Agency 2020)

The advantage of EV is that it does not produce direct emissions while driving. The CO_2 life cycle emissions may be small if the electricity is produced using renewable energy sources. NOx and particulate matter emissions produced by combustion affecting human health are reduced compared to vehicles with combustion engine. The downside is that the negative health impact concentrate more on the upstream processes compared to combustion engine. (Helmers et al. 2020) Negative health impacts have also been linked to possible battery fires during traffic accidents (Sun et al. 2020).

4.2 Cobalt mining industry in DRC

Almost 70 % of world’s cobalt is produced in DRC (USGS 2021). Cobalt is mined in Lualaba and Haut-Katanga provinces in southern DRC. 70 % of cobalt and copper from DCR origin are produced in Lualaba province (Respondent 5).

Mining is done at industrial (LSM) and artisanal level (ASM). About 80 % of the cobalt comes from industrial mines and 20% from artisan miners. (BGR 2019; Sovacool 2019; Banza Lubaba Nkulu 2018) In 2017 19 000 tons of cobalt was extracted by ASM workers, and there were around 80 artisanal cobalt mines in DRC (CRU 2018; van den Brink 2020). According to BRG (2019) the estimated ASM cobalt production was 12 300 tons in 2017 and 17 960 tons in 2018 based on the assumption that the share of ASM cobalt was 15 % of the total exported cobalt reported by DRC's ministry of mines. According to one interviewee the share of ASM cobalt of all cobalt is difficult to estimate since currently many of the miners work informally for the LSM companies, which buy the cobalt directly from the miners (Respondent 3).

It has been estimated that possibly as much as 1 million people depend on the mining industry in one way or another (Frankel 2016). Large scale mining has been estimated to employ between 3000 to 30 000 Congolese people (Sovacool 2019; Respondent 5; Industriall 2018). Artisanal mining employs between 110 000 and 225 000 people depending on season (Amnesty International 2016, 16; Kara 2018; Respondent 5).

There are differences in safety, working conditions and salary, when comparing two mining practises. Industrial mining is safer and better paid than artisanal mining. Artisanal mining is done by hand digging in underground pits whereas heavy work machinery is used in industrial mining in open pits. (Sovacool 2019) LSM is performed by large Western or Chinese mining companies. (Sovacool 2019)

Biodiversity and soil degradation is caused by mining activity. Mining activity demands more and more land. As a result, there is not enough agricultural land to support everyone. (Cordaid 2015) Mining companies cut down trees and use them to build property. Losses are not often compensated to local communities. (Sovacool 2019) One interviewee explained that due to the environmental destruction caused by mining activity people are poorer than they used to be (Respondent 2). This is partly because mining has affected soil quality and ability to farm as livelihood. Farming is the main livelihood for 75 % of the people. (Cordaid 2015)

Democratic Republic of Congo has long history of exploitation and conflicts, both of which have caused damage to people and environment. Conflicts are centered to eastern DRC, which is not cobalt mining area but have affected the mining activity indirectly. The environmental pillage and humanitarian terror started already in late 1900th century with palm oil and natural rubber farming. The DRC mines were utilized already during world wars to produce bullets. The uranium used in Hiroshima atom bomb was originally from Katanga region. (Baraza 2020)

DRC has large reserves of earth element resources that could advance its financial development. However, due to poor state of natural resource and finance management and corruption, people do not profit from the mining activity. The export of the mining products is not taxed enough, and some companies do not pay taxes even if they legally obligated. (Respondents 3,4,5)

One of the latest and largest corruption schemes was revealed in 2021. Human rights watch organization RAID estimated that DRC may have lost 1,95 billion USD revenue and will probably lose 1,76 billion more in royalty payments in the future due to businessman Dan Gertler. Dan Gertler has been involved in DRC mining sector over decades. (RAID 2021) His close relationships with former DRC president Joseph Kabila and former USA president Donald Trump helped him to exploit DRC even though his actions have been acknowledged for years. Gertler’s actions include acquiring mining licenses, investing in large mining companies and paying bribes, while claiming to build sustainable economic recovery. (BBC 2021)

4.2.1 Artisanal mining

There are different types and definitions of artisanal mining. Some miners find unoccupied mineral deposits and work there, whereas others mine clandestine in areas that belong to industrial mining companies. Formal ASM areas has also been established but they are often far away or inaccessible. (Afrewatch 2020a, 11) One respondent explained that sometimes ASM workers find new cobalt ore deposits first, but then large mining company buys the site from government and drives ASM workers away. (Respondent 6)

ASM workers often concentrate on collecting heterogenite, which is mineral containing only cobalt without copper (BGR 2017). Chinese Huayou Cobalt (Congo Dongfang mining) is one of the actors in DRC cobalt mining industry. It sells cobalt products to EV battery manufacturers. (Amnesty International 2017, 4) It is the only company buying cobalt openly directly from ASM miners (Ericsson et al. 2020; Calvao 2021).

The artisanal mining started in 1990s when the state mining company financially collapsed. The Congolese civil wars have also increased the artisanal mining. Often people do not have other employment options. (Amnesty International 2016, 5) On the other hand, cobalt mining has been compared to gold fever and it sometimes attracts young and adventurous people dreaming to acquire wealth (Niarchos 2021).

The whole local community is often involved in artisanal mining including women and children. Men are usually engaged with the most dangerous part of the cobalt mining digging in underground tunnels whereas women, and children work at collecting cobalt rocks on the surface around LSM mines or old mine tailings. Women and children also wash and transport ore (Amnesty International 2016, 5; Sovacool 2019). Children can be sometimes used in digging to access narrower galleries (World Vision 2013). Approximately 60-74 % of the ASM miners has been estimated to be diggers (Tsurukawa 2011; Elenge & De Brouver 2010).

Geenen et al. (2021) studied formal ASM gold mining in DRC. She recognized 8 types of workers with different job descriptions. Pit manager is usually starts the process and invests to the mining operation. Conducteurs are people that oversees the exctraction process and capita are daily supervisors of teams. Boiseur stabilize pits by constructions, foreur is another term for diggers, pelleteurs transport rock and sand from the pits, machiniste are in charge of oxygen pumps and prospectors search for the best gold veins. The share of different workers is pit manager (9,3 %), conducteur (12,8 %), capita (4,2 %), boiseur (6,4 %), foreur (21,4 %), pelleteur (44,4 %) machinist (1,3 %) and prospecteur (0,2 %). It is likely that the cobalt miners have similar hierarchies since they also work in groups.

4.2.2 Occupational hazards

ASM diggers working in tunnels are in danger to die or injure in different accidents. They may fall in the tunnels or get crushed by falling rocks. There are cases of fatal accidents caused by collapsing tunnel. If the mine is too deep, they may run out of oxygen and suffocate. Some ASM miners pump oxygen to the deep tunnels, but it is dangerous due the possibility that the device stops working. Some workers use fire to break the rock easier, but the fire may burn the oxygen away from tunnels killing the miners. (Amnesty International 2016, 23-25) Sometimes ASM workers dig under the residential areas of local communities causing fatal landslides and collapses (Sovacool 2019).

Annual death rate of the ASM miners has been estimated to be 0,4-0,5 % (Tsurukawa 2011). BGR (2019, 40) reported 63 fatal accidents and 101 accidents leading to injuries during 2018 in artisanal mines studied whereas Amnesty International (2016, 23) estimated 80 deaths in time period of 1 year in 2014-2015. ILO (1999) estimated the rate of fatal accidents to be 2,5 % in ASM type mining in general. Accidents also concern LSM workers. Due to a landslide 7 mineworkers were killed in open pit mine in 2016. (Industriall 2016) There were no statistic available considering LSM accident mortality in DRC. The 10-year-fatality frequency of LSM in Ghana has been estimated to be 0,0071 per 1 000 000 working hours. In the same study 38-47 year-olds were identified as the age group having most fatal and non-fatal injuries. (Stemn 2018) Similar age group had most of the injuries also in study concerning Turkish mining industry. The non-lethal accident frequency rate in open pit mining in Turkey was 5,65 per million working hours. (Onder 2013)

The danger of accidents present in the LSM in general makes the working conditions stressful. There are challenges in both underground and open pit mines e.g., regarding to darkness, noise, dust, temperature and ventilation. Being constantly alert to ensure the safety of everyone may increase stress. (TTK 2015) Due to stressful working conditions higher amounts of mental health disorders are detected in mine workers compared to people working in other professions (Deng et al. 2017).

Whole-body vibration caused by mining tools and vehicles used in LSM may cause pain and different disorders in long-term exposure. The impacts of vibration were studied in open pit coal mine in India. Workers experienced pain in multiple body parts: neck (47,61) %, shoulder (42,85%), elbows (7,14%), hands or wrists (16,66 %), upper back (19 %), lower back (83,33 %), hips or tights (14,28 %), knees (42,85 %) and ankles or feet (11,90 %). (Jeripotula et al. 2020)

Elenge et al. (2013) studied occupational accident related to ASM mining in Katanga. The median age of the diggers was 25 years. 83,3 % of the miners had been over 3 years in the profession. Most of the workers were 19-37 years old. There were 392 accidents reported during the 12-month survey 72,2 % of the workers being subject to at least one accident and 60 % at least two accidents. 51,5 % of the accidents were caused by handling tools, 32,9 % of the accidents by handling heavy weighted loads, 11,5 due to falling and 4,1 % due to running out of oxygen in the tunnels. 23 % of the workers that had an accident were under the influence of alcohol and 12,8 % were on drugs. Some of the miners drunk before or during the work shift. About half (52,8 %) of the workers were classified as great consumers of alcohol and 89 % used benzodiazepines e.g., to be better able to sleep. The possibility to die or injure in an accident causes anxiety. Some ASM miners drink alcohol while working to be able to forget the danger. (Amnesty International 2016, 21; Sovacool 2019) The injuries resulted the workers being absent from work, 50,8 % being absent for 3 or more days. This influenced the workers’ ability to support themselves. ASM workers that had participated in apprenticeship had less accidents (26,1 %) compared to workers that had not (46,1 %). (Elenge et al. 2013)

Artisanal miners working in pits breath in dust frequently and often have permanent cough, which could be a sign of silicosis. The dust also irritates eyes. (Sovacool 2019) Silicosis is a lung disease caused by inhalation of crystalline silica dust. Silica can occur naturally in ground e.g., in a form of quartz. Silicosis is a challenge especially in developing countries, where fewer protective measures are used. Silica is also linked to other pulmonary conditions e.g., lung cancer. Lung cancer has been detected to occur after 15 years latency time. Silicosis has at least 10 years latency time with low concentration exposure. Accelerated silicosis takes 5 to 10 years to develop after exposure. Rapid exposure to large amounts of silica may cause acute silicosis. (Leung 2012) However, since the life expectancy in DRC is currently 60,7 years and the latency time for lung cancers and diseases is long, they have little effect in lost life years. Lung diseases and cancers are often diagnosed at the age of 60 or higher. They will become a greater challenge in Africa if the life expectancy gets higher. (McCormack & Schüz 2011; World Bank 2019a)

The ASM workers are also exposed to arsenic in gangue and washing pools. Radioactive radon gas, rising from the grounds as decay product of radium, may be inhaled. The official artisanal working areas do not have sanitary facilities which increases contamination risks. The occupational symptoms are different in different mining jobs. Crushers are in risk to have eye injuries caused by stone fragments or finger injury due to hitting themselves with hammer. The loud noise caused by hammer may cause hearing problems. The working position causes also challenges. Washers are exposed to different bone and muscle injuries. ASM diggers suffer from cough (17 %), headache (80,3 %), lower back pain (76,7 %), upper limb pain (18,3 %) and dermatitis (1,7 %). Non-diggers experience cough (10 %), headache (44,7 %), back pain (67 %), lower limb pain (26,5 %), upper limb pain (8,6 %) and dermatitis (5,7 %). (Elenge & De Brouver 2010)

4.2.3 Women in artisanal mining

Women are not usually involved in LSM, because they are forbidden to go to the mining sites. (Katz-Lavigne 2019) Some women are involved in the ASM digging, but they mostly do other mining related jobs (Sovacool 2021). According to a report by Afrewatch (2019) women suffer from artisanal mining works (Amnesty International 2016). Women ASM workers are in weaker position than men because they are often excluded from financial decision making and organization of mining teams. They also earn less money compared to men. Discrimination due to gender is cultural and women sometimes having denied access to mines is based on the belief that their presence makes minerals disappear from the site. The lack of childcare options has forced women to bring their children to the mines while they are working. This has even been linked to children starting to work at the mines when they come to an age when they are physically capable to do that. Spending time in contaminated and unsanitary mining environment is bad for the children’s health. (Hayes and Perks 2012)

Women in local communities have less opportunities to affect their situation and participate. Mostly men are involved in open house activities with mining companies. Rural women are affected by land alienation, expropriation and water and environmental pollution. No compensation from resettlement and agricultural losses. Women only have user rights to property through their husband or sons who are the lawful owners. Therefore, they are not included to consultation and compensation. Women are ignorant of their rights. (Afrewatch 2019; Cordaid 2015) Due to lack of education women in ASM are rarely aware of new laws or measures putting them in disadvantageous posture when dealing with state officials compared to men (Iguma Wakende 2021). Women are often more affected by pollution since they are more in contact with the river water than men. They are also more likely to get genital infections due to working in water. (Cordaid 2015; World Vision 2013)

4.2.4 Child Labour

Child labour is common in DRC (Frankel 2016). It has been estimated that 35 000-40 000 children are involved in mining activities of different minerals in DRC (Amnesty International 2016, 6; Kara 2018). The number of children working in cobalt mining was estimated to be 2500 in a field study. However, the study only included children under 15 years old. (BGR 2019, 43) Another estimation of children working in ASM was total of 10 000 in Katanga and Lualaba provinces (Respondent 4). It is roughly estimated that about half of the children work in a hazardous condition meeting the conditions of worst forms of child labour (BGR 2017).

Not all work performed by children is problematic, but often working too many hours has an effect on attending school and getting education. Not having education affects the child's future salary and standard of living. The child labour in mining is considered hazardous since it happens in dangerous and unhealthy conditions, which is one definition of the worst forms of child labour. Working in cobalt mining is energy and time-consuming making participation to school difficult. In several interviews' children working in mines have also complained about getting sick easier and their body aching because having to carry too heavy loads of minerals. (Amnesty International 2016, 6; ILO 2021) Mine workers with better education were more likely to earn more and be in higher positions in mining groups' hierarchy compared to less educated miners according to a study concerning DRC artisanal gold miners (Geenen et al. 2021).

Working in toxic and dangerous environment is more harmful to children than adults. Due to their physical traits, they absorb toxic easier and inhale more dust compared to adults. Their brain absorbs and retains more heavy metals, and their endocrine system can be disrupted by chemicals. Children's systems are less able to detoxify chemicals. (ILO 2011, 13) According to a study by World Vision (2013) 30 % of children working at mines complained about nausea, which can be caused by copper ingestion. Vision impairments and eye pain affected 25 % of children and 34 % had skin irritation. Persistent or frequent cough was experienced by 67 % of the children. Body pain was experienced by 87 % of the children. (World Vision 2013, 28)

Children can earn 1-2 USD/day and often work 10-12 hours/day even when they attend school. Some children work only seasonally e.g. during holidays. Working offers some of them possibility to pay for school fees (Amnesty International 2016, 6). Some children feel happy about working in mines or consider it as a social event because they do not have anything else to do. (Sovacool 2021). On the other hand, Children are often abused or cheated in trade (Amnesty International 2016, 6). Sometimes children are even claimed to be drugged in order to them to forget their hunger while working (Niarchos 2021). Sexual harassment of the children is considered rare (World Vision 2013).

Only 75-80 % of children go to school in mining provinces (Respondent 8; UNICEF 2019). Girls are more often illiterate or have never attended school compared to boys (Afrewatch 2019). This is not a direct effect of Cobalt mining industry but may impact on their chances to participate decision making as mentioned in the previous subchapter. Education is free in DRC, but due to poor financial funding children must often pay monthly 10-30 USD fee to attend school. If the family is poor or the parents are unemployed children have no other option than stay at home or work at the mines. ASM increases the possibilities of children attending to school thus they can afford the school fees. The multinational mining companies are cautious about child labour and have zero tolerance against it. (Sovacool 2019; Amnesty 2016)

The LSM mining companies are in a difficult situation even though they do not allow child labor themselves. The children working in AMS may collect ore around the mining site which may cause accuses child labor being used. Not allowing children to collect rocks near mines may cause conflicts with locals. (Sovacool 2021)

4.2.5 Fair wage

ASM workers may work in 24-hour-periods. Spending full day in the tunnel then having a one-day break and then spending another full day again in the mining tunnel (Amnesty International 2016, 6). Diggers dig in 2-hour shifts in the official ASM areas (Elenge & De Brouver 2010). According to Sovacool (2019) ASM workers can extract 30-50 kg of raw ore per day earning 1-3 USD, which makes 30-90 USD per month. One clandestine ASM worker explained that they can work 3-4 hours per day before the mine guards chase them away. (Respondent 7) Women working as washer can wash 8-12 sacks of cobalt ore and earn 1,5 USD/day, which makes 45 USD/month (Amnesty 2016). According to one respondent the working times are long, about 10 hours/day, at LSM and they work without vacation days or over time compensation. The same interviewee also claimed that subcontracting workers have no protective equipment. (Respondent 4) However, an LSM miner, who was interviewed in another study said that they use protective equipment for example dust masks and respirators. He also explained that shifts are 12 hours long and they are working 7 days a week. (Sovacool 2019) Working in 10-12 hours shifts is not untypical in mining industry in high income countries like Finland, but then longer vacation periods should be allowed (TTK 2015).

Workers in LSM company can earn 300-1000 USD per month. Congolese engineers can earn 400 USD whereas the salary for a chief can be even 1000 USD. (Respondent 8). Salary of normal labourer in Chinese company is estimated to be between 100 and 300 USD/month. Often Chinese workers earn 1500 USD for doing the same job, which makes the Congolese salary unfair. Western companies usually pay 300 USD/month. (RAID 2009) According to study by Raid (2019, 34) KMT mine worker salary varied between 200-500 USD/month depending on job description average salary being 322 USD/month. To put the salary on scale artisanal gold miners, have similar earns to LSM cobalt miners (pit managers 191 USD their right hands 92 USD experts 52 USD and pelleteurs 24 USD per week), whereas teachers has been reported to earn 30-50 USD/month and farmers 1 USD per day (Geenen et al. 2021).

According to FairWage database (2016) the minimum living wage of one family is 17 USD per month. This is however too low to cover even the school fees of the children, which makes it unreliable. According to Fairphone (2020) Unicef calculated minimum amount of money needed per month to survive in a crisis situation to be 373 USD for 8-person-household. The original report of the study was not to be found anymore. Based on those calculations Fairphone, mobile phone manufacturing company, estimated minimum living wage for 8-person-household if parents work in mining to be 324 USD per month. The difference between those two estimations is that in crisis situation all the utilities have to be bought new. (Fairphone 2020) However, instead of 8 persons the average family size in cobalt mining provinces is 10 persons (MPSMRM 2014). Both calculations also failed to estimate the size of the monthly school fees, which often are up to 30 USD per child even though the education is considered free (Amnesty 2016). World Food Programme (2020) calculated expenditure baskets for 6-person-family. Minimum expenditure basket was estimated to be 178,23 USD and survival minimum expenditure basket to be 109,62 USD. Earning less than survival expenditure basket means death.

There are some controversies in different reports considering the financial effect of cobalt mining. Amnesty International (2016, 27) emphasizes that people working on mines earn so little they barely afford to eat whereas Sovacool (2019) argue that miners has better financial situation compared to others and mining is way out of poverty for many people. Also interviews made by Katz-Lavigne (2020) suggests that mining is a way out of poverty for some miners. Some are for example able to save money to start their own mineral trading business. However, it is argued that the health and social effects of ASM are too severe to improve the quality of life (Perks 2011).

Miners may earn more than people working in farming, but the security payments and informal taxation take their share of their earnings. Often same structures control both mining and the sale of basic resources e.g., food. (Perks 2011) ASM mining is income source mainly to poor and uneducated or lacking skills (Zvarivadza 2018).

Structures and mechanisms of ASM are exploitative. Polices earns money by exploiting the clandestine workers at LSM sites. Even some government authorities exploit the situation by selling informal mining licence cards to the workers or being involved in clandestine mining. Most profits are made by Chinese, Indian and Lebanese mineral buyers. Corrupted government officials may also buy ASM mineral illegally at low price and want to prevent development of the sector. (Zvarivadza 2018)

4.2.6 Conflicts

Conflicts are linked to artisanal mining. Many artisanal miners work in an area that they are not originally from. This may cause some conflicts between area’s indigenous residents. (Katz-Lavigne 2020) The illegal ASM workers often have conflicts with mining police (Sovacool 2019). Clandestine miners are sometimes abused when they are illegally working in LSM sites. There have been cases, where abuse has been fatal. (Katz-Lavigne 2020) In addition to violence the illegal miners often face incarceration if caught by the security. Miners are required to pay fee to get out of jail. (Katz-Lavigne 2019) According to Respondent 6 if the miners try to strike, an army is sent to force them back to work causing a lot of violence. Occasionally ASM miners are shot and killed especially if they go to the mines illegally (Tsurukawa et al. 2011). The mines are getting more and more militarized. Military and police have killed dozens of people. Milder forms of violence and robbery also occur. These kind of conflicts and harassment makes the life of the miners, dealers, and traders stressful. (Sovacool 2019)

4.2.7 Collective bargaining

Industriall, which is global worker union federation, reports at least 4 mining related worker unions in DRC: TUMEC, CSC, UNTC and OTUC. For example, workers of Glencore and Gecamine mines are part of the TUMEC. (Industriall 2018a) In the future, TUMEC aims at organizing workers from subcontractors and artisanal mines. It can be considered as established union e.g., in Kolwezi and Lubumbashi mines and it has been planning to start targeting also Mutanda and Kamoto mines. (Industriall 2018b)

There have been successful strikes by the LSM workers and unions. One strike concerned 12 000 people working in Tenke Fugurume mine who were confined in the mining area due to COVID-19 pandemic. They were paid allowances due to mistreatment, where the workers were not allowed to commute from home, but they were forced to live in the mining site to avoid getting the corona virus. (Industriall 2020) ASM workers do not have negotiating power (World Vision 2013). According to multiple studies there has not been signs of forced labor in cobalt mines (BGR 2019; Tsurukawa 2011).

4.2.8 Social security

There is no proper social security system in DRC. If someone gets sick or is injured, they must pay for the treatment by themselves. Also, they often must walk long distances to get to the hospital. (Afrewatch 2020a) A new taxation system in order to create some sort of social security has been established recently. Workers pay 5 % of their salary for health insurance. Pension, disability, occupational accidents and diseases, maternity and family expenses are paid from that insurance if the insured has been in coverage for required time. The insurance concerns formal working sector only. (Office of Retirement and Disability Policy 2019) Another option is voluntary mutual health insurance that a worker can join. It covers 80-85 % of the medical expenses. There are also different humanitarian aid organizations offering help using methods like cash transfers and vouchers intended for the poorest people. (Tull 2018)

4.2.9 Local employment

Mining code demands that the mining companies should use local workforce, but usually the local workers do not have required skills to work in industrial mines (Respondent 5). Professionals that are needed in mines are e.g., plumber, cartographer, electrician, topographer, engineer, chemist and geologist. From the LSM mining company point of view the employment of the locals is difficult since they lack the skills, and it is not possible to employ everyone. Often the communities around do not have secondary schools, which reduces the possibility to get a good education. On the other hand, locals feel that LSM companies do not want to employ them for even simple tasks. (Cordaid 2015, 25-27)

Locals often have only short-term working contracts with LSM companies. If local people are employed by mining companies, the duration of the employment is often 21 days. After that they hire new person for the same job. Same persons may be employed again after 5 months. This all is due to legislation, because after 21 days there would be some responsibilities to the company towards the employee. (Respondent 8; Cordaid 2015, 27) The employment of the local people seldom benefits the rural communities since the employees often move to nearby larger city probably due to better living conditions (Cordaid 2015).

4.2.10 Local community pollution exposure and diseases

Cities and villages are often built around mines making them vulnerable to damage caused by mining accidents and pollution. In some cases, the local community is highly dependent on the mining activity. If the nearby mine is closed people may lose access to e.g., healthcare, and clean drinking water. (Respondent 8)

Pollution may cause different health effects in communities near mines. High concentrations of different metals e.g., cobalt, manganese, uranium and nickel in people living near mining sites have been detected in urine test. High exposure to cobalt causes multiple medical conditions affecting life quality. These are for example, lung diseases (asthma, hard lung disease), dermatitis and thyroid conditions. (Banza Lubaba Nkulu 2009; Banza Lubaba Nkulu et al. 2018; Respondent 9). Persistent cough is highly common in mining communities (World Vision 2020). In addition, polluted water causes diseases like diarrhea (Cordaid 2015).

Lead, copper and manganese have been connected to birth defects. Normal appearance of birth defects is 1 major birth defect per 33 births. A study showed 0,1% having birth defects in mining area. The percentage of fathers working in mining industry was higher among children with birth defect. A previous study of the same group also suggested that mothers living closer to mining and refining sites were more likely to have child with birth defect. (Vaan Brusselen et al. 2020) DRC has one of the highest newborn mortality rates birth defects being one of the main reasons for that (WHO 2020a).

Following health impacts have been linked to trace metals found in high quantities by Banza Lubaba Nkulu et al. (2009; 2018). Copper exposure can cause liver and kidney damage, anaemia, immunotoxicity and developing toxicity. In addition, nausea, vomiting and abdominal pain are symptoms of high copper ingestion. (ATSDR 2004) Exposure to uranium has been connected to kidney cancer and kidney failure. This due to uranium being filtered by kidneys (ATSDR 2013). High manganese exposure may cause neurological effects especially in children, but it may cause life complicating functional difficulties also in adults (ATSDR 2012). Nickel is recognized to be carcinogenic and cause skin irritation due allergy. It also causes lung diseases. (ATSDR 2005)

Cheyns et al. (2014) studied pathways of human exposure to cobalt in DRC. The concentrations in children were higher than adults. The main exposure routes were eating maize flour and legumes, which were grown in polluted soil. Dust was also significant exposure pathway when considering children. High exposure in small children might be due to having soil as house flooring instead of covering it (Smolders 2019). Eating soil as an exposure route in general has also been recognized in a study by Xie et al. (2017).

The overall health in the communities near mining site is worse compared to other areas. There is a greater risk of HIV, diarrhea, hepatitis, meningitis, bilharziasis, cholera, typhoid, tetanus, typhus, malaria, yellow fever, and tuberculosis. (Tsurukawa 2011, 29) In a study related to ASM in Ghana, 80 % of the ASM community reported malaria symptoms, whereas 67 % of agricultural community had similar symptoms. This may be due people from ASM community living near standing water more often compared to agricultural community. (Basu et al. 2015) Large portion of malaria deaths (67 %) is in age group children under 5 years old. Other groups vulnerable to malaria are pregnant women and HIV patients. (WHO 2021a).

The HIV prevalence of people living in ASM mining areas, who were tested was 7 % in 2013, whereas the normal prevalence in DRC was 0,8 % in 2019. (GSS 2013 according to Schwartz et al. 2021; UNAIDS 2021) Similar difference between prevalence has been noticed in Ghana (Adjei et al. 2014 according to Schwartz et al. 2021). The coverage of HIV treatment is constantly increasing being 74,5 % in 2020. The HIV prevalence among sex workers in DRC is 7,5 %. (UNAIDS 2021)

Waterways are blocked and polluted by the mining operations. People are used to drinking from natural sources. Water price is high. Residents need to pay for the treated water that does not cause sickness. Earlier there was a public tap provided by a former mining company working in area, but the mine closed. (Respondent 8) Drinking water quality has been studied in mining areas. Higher amount of trace elements and coli bacteria has been found compared to other areas. (Banza Lubaba Nkulu et al. 2018; UNICEF 2019) The overall amount of people drinking from unprotected water sources in cobalt mining provinces is high. The share of people drinking from unprotected water source in Lualaba province is 56 %. (UNICEF 2019)

4.2.11 Forced evictions

Forced evictions cause conflicts. In one neighborhood in Kolwezi people were evicted from their homes, because rich cobalt mineral was found under their houses. (Respondent 6) In 2019, 10 000 families were relocated to expand mining area and in 2018 600 families were evicted from a different area. In both cases compensations were paid to families. (Kannah 2019; Amnesty International 2019) There were also forced evictions in 2009, where a residential area was bulldozed to the ground by a cobalt and copper mining company (Amnesty International 2018).

Communities of indigenous people are displaced and migrated by the LSM companies in order for the companies to be able to construct their own buildings or infrastructure there. Traditional hunting ground and agricultural areas may be closed causing food insecurity. Also, malnutrition is caused by inflation due to miners outside local community who have more money to spend than locals. (Sovacool 2019)

4.2.12 Other autonomy infringements

Forced labor, debt bondage and human trafficking have been studied in eastern DRC, but since the situation there is completely different compared to Copperbelt the results can not be applied in this study. (Schwartz et al. 2021)

Cuvelier (2014) studied masculine roles among Katangese AMS miners. Mainly young miners have adapted themselves edgy identity with an attitude that societal rules do not apply to them since their style of life differs from other people. They gain respect from each other by showing no emotion and acting calm during dangerous situations. They distinct their subculture from other people in several ways like deviant behavior and having their own slang. Buying expensive clothes, alcohol and drug use and prostitution is also part of this culture. Older miners with children usually behave more responsible. The separative culture has been mentioned one of the reasons children involved with mining having difficulties going back to school and different kind of life. Alcohol and drug abuse can also lead to addiction forcing miners to work in mines to earn money to buy more substances (Sovacool 2021; Niarchos 2021).

The violence is caused by substance abuse and social problems concentrated on the mining areas. Prostitution has also been recognized as one of the side effects of mining activity. There is also higher rates of theft, violence and sexual abuse. (Sovacool 2021; Hayes and Perks 2011) In eastern DRC conflict areas, where other minerals than cobalt are mined, sexual violence is used as punishment to prevent poaching and mineral trafficking (Rustad 2016). This or other challenges linked to the eastern DRC should not be confused with social challenges in DRC Copperbelt, which situation largely differs from conflict areas.

According to study performed near Kolwezi 65 % of local children had been subject to violence. All interviewed women had suffered from violence caused by sexual partner and 75 % of them had faced sexual violence. Due to sexual violence 45 % of women had considered suicide at some point of their lives. (GSS 2013 according to Schwartz et al. 2021)

4.2.13 Positive impacts

It must be emphasized that government makes positive efforts to improve the situation with social impacts of mining industry (Respondent 5). In addition, NGOs work on the matter (Respondent 4). According to Zvarivadza (2018) formalization of ASM would benefit all parties. ASM workers can mine in the areas where large scale mining is not profitable. Formal ASM areas would reduce the risk of conflicts and illegal taxes and stabilize the income of ASM miners. It would also protect the miners from forced evictions. Province of Lualaba has invested 32 million USD to building and development of trading center and ASM mining area (Afrewatch 2020a).

In formal artisanal mining areas, open spaces are cleared so the miners do not have to dig tunnels and are able to access the ore easier. On the other hand, people were forced to move from their homes to be able to create the area. They also train cooperatives to supervise the mining activity in formal artisanal mining areas. Working with cooperative is required from miners. Cooperatives are trained in finance to create a new middle class. (Respondent 5)

Mining companies often improve infrastructure because it benefits their activities. Some companies build schools and hospitals for their workers. (Sovacool 2019) Benefits of those are uncertain to the local community. Some cases the mining companies have built good hospitals for their workers and badly equipped hospitals to local people (Cordaid 2015).

The mining code of DRC was revised in 2018 to improve the situation. One of the main goals was to increase sustainable development in local communities. After two years of revision many aspects of it are not applied in practice or they are only partially implemented. (Cordaid 2020)

Mining code requires that social and environmental aspects are included in mining project. It demands that companies must sign a contract with local community in presence of local authority. The contract must be accepted by commission and if the promises are not fulfilled there will be sanctions. There is also environmental certificate that is provided by the authorities. If the terms of the certificate are not met, it can be taken away and the operations of the mine in concern are shut down. (Respondent 5; Cabinet du Président de la République 2018)

New mining code states that 15 % of the mining royalties should be paid to the communities. During the previous law they were transferred to central government, but now they are received by Decentralized Territorial Entities. Money is used in community development like building hospitals and infrastructure. Mining code requires companies to have plans on how to contribute to community development. Community development funds have been developed. Mining companies should pay the minimum of 0,3 % of the production to community development. Pact Congo is an organization funded by mining companies. It is supposed to use the money to improve mining affected communities e.g. to reduce child labor. (Respondent 5; Cabinet du Président de la République 2018)

The old mining code allowed mining companies 10-years-time to stabilize their operation before being required to pay for community development. This has been changed in the new mining code to benefit the communities. (Respondent 5; Cabinet du Président de la République 2018)

4.3 Transportation of cobalt in and from DRC

Cobalt from ASM origin is first transported to a dealer and then exported from DRC. Then cobalt is transported from DRC to Tanzania or South Africa usually by tractor trailer. From there it is transported by ship to Asia, usually to China. (Frankel 2016)

Transporting cobalt ore from mining site to dealer can be dangerous. People are sometimes robbed, or they may disappear never coming back. Children carrying ore next to road are sometimes run over by cars. (Sovacool 2019) Transportation can also be carried out by motorcycles or bicycles (Sovacool 2021). Sacks as heavy as 70 kg are loaded on the bike and the vehicle is pushed, because it is too heavy to pedal. The transportation to the trader may take from 10 to 12 hours and is dangerous due to other traffic. Lifting and carrying heavy sacks cause health problems. (Sovacool 2019)

There has been traffic accident related to transportation of refinery chemicals. In one incident sulfuric acid tanker truck was knocked down causing death of 21 people. 7 people were severely injured. (Afrewatch 2020b) Mining related road transport near residential areas also increases the amount of dust in houses causing health effects according to Respondent 8.

4.4 Cobalt refining

Cobalt is partially treated in DRC and partially in China because untreated cobalt ore and cobalt concentrate export has been forbidden since 2013. Currently, there is a special permission to export unrefined products due to insufficient treatment capacity in DRC. The aim is to increase the value of exported goods so the country could better benefit from the mining industry. (Reuters 2020)

Different kind of cobalt products e.g. cobalt metal, cobalt hydroxide and cobalt alloy are produced using different pre-treatment and refining methods. Different methods can be smelting, acid leaching and hydrometallurgical treatment. (Crundwell 2020) The refining steps before acid leaching take place in DRC. Acid leaching is very energy intensive which is why it is mostly performed in China. (Dai et al. 2018) Even though the copperbelt is unified zone the geology differs between areas. Cobalt can be found in different forms e.g., malachite, pseudomalachite, cuprite, heterogenite and asbolane. The treatment process varies between different forms. (Santoro et al. 2019)

Sulfuric acid, used in acid leaching, can be imported, or produced at the refining plant. Imported sulfur comes from Turkey or middle East. Sulfuric acid can be also imported from Zambia, which is a neighboring country. Some of the refineries have their own sulfur burning acid plant. Sulphur can be produced as a co-product of copper refining. (Crundwell et al. 2020) Acid leaching of some cobalt minerals require use of reducing agent. Sodium metabisulfite is commonly used reducing agent in the process. (Santoro et al. 2019)

Refinery workers in DRC have to carry heavy sacks of cobalt, which causes pain in the body. Cobalt is manually crushed in the refinery. Manual crushing is physically demanding, and workers have reported to be often sick or injured. (Elenge & De Brouver 2010; Amnesty

International 2016) There are no available records of social sustainability impacts on workers caused by acid leaching.

There is little data available considering environmental impacts of acid leaching in China or DRC. It may also be difficult to separate the impacts of acid leaching from mining activity and smelting in DRC since all operations occur in the same area. Copper smelting causes damage to vegetation and soil resulting deforestation and erosion in downwind from smelter. It also creates similar dust as mining activity. (Shutcha et al. 2015) Burning of contaminated plants, litter, and soil biomass to produce energy causes pollution. (Mihaljevič et al. 2016). Energy is needed in acid leaching process as catalyst (Santoro et al. 2019).

In 2016 Sicomines' plant leached chemical substance to Luilu River. Over 6 000 people living nearby were affected. The accident caused damage to property and human health. Fish at the river died and around 30 suffered from severe symptoms. Being in contact with river water caused headaches and bleeding. In addition, there were long time health effect since the water was also contaminated in the wells and could not be drunk or used in irrigation. Since agriculture was the main livelihood in the area this had also other major social effects especially because part of the farmland was destroyed due to explosions caused by the incident. (Afrewatch 2017, 17-23)

Acid is used in the ore treatment and it leaks to the water and fields destroying them. Fishers and farmers suffer because it affects their livelihood. In some cases, acid has leaked to surface water and children playing there have been injured (Respondent 10). Also, applying processes that consume a lot of water in already dry area is problematic (Crundwell et al. 2020).

Harmful SO_3 and SO_2 emissions are linked to Sulfuric acid production. (King et al. 2013) Sodium metabisulfite may cause SO_2 emissions (US5753200A 1996). SO2 exposure has been studied in urban areas in China. It has been linked to cardiovascular diseases and related mortality (Wu et al. 2020), birth defects and crop damage caused by acid rain (He et al. 2017). The social impacts unrelated to environment are more difficult to assess because lack of data.

5 SOCIAL LIFE CYCLE ASSESSMENT OF COBALT MINING

The goal and scope of the SLCA study is defined in this chapter. Inventory data is collected and severity weights concerning impact assessment are presented.

5.1 Goal and Scope

The goal of this desk-study was to quantify generic social sustainability impacts of cobalt production in DRC. The results are used in identifying how cobalt mining impacts on human wellbeing and what are the most significant impacts. This study concentrated on two affected stakeholder groups: workers and local community.

The function of the product system, modelled in this SLCA study, was to produce cobalt ore. Pure cobalt was used as a reference flow. The functional unit of this system was production of 1 kg of pure cobalt.

System boundary of this study was cradle-to-gate including mining related activities concerning ASM and LSM mine workers and local communities were included. Energy production needed for vehicles and tools in LSM was excluded. Chemical processing of the mineral was excluded. Transportation was excluded. System boundary concerning cobalt life cycle stages linked to LiB manufacturing are presented in figure 1. All cobalt mining stages included in this study were handled as one process per stakeholder group since most cases it was difficult to differentiate the impacts of e.g., mining and crushing from each other.

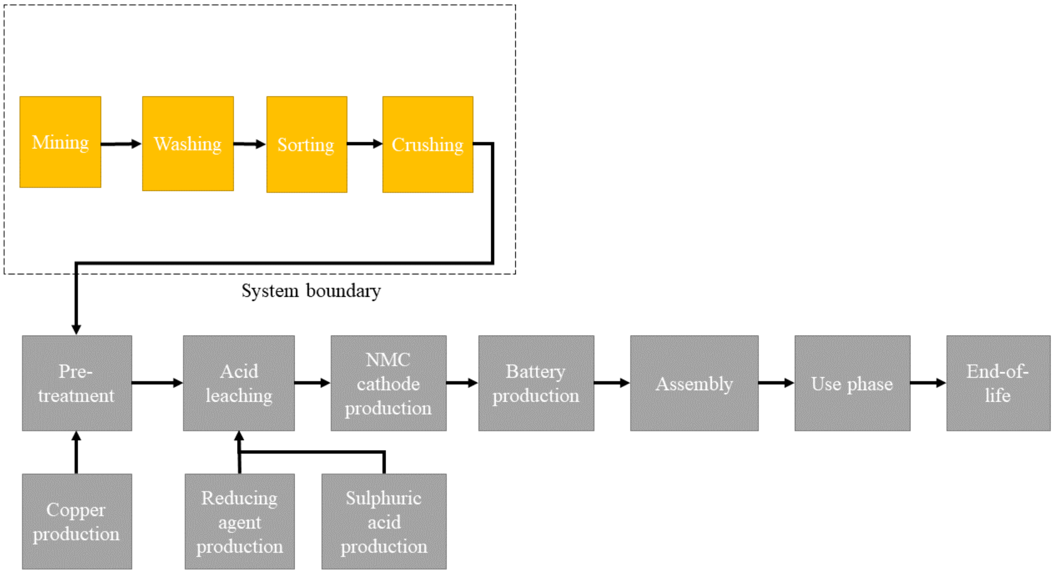


Figure 1. System boundary of cobalt production/LiB manufacturing system

All data used in this study was average and generic. No site-specific data could be acquired due to restrictions caused by COVID-19 pandemic. No stakeholders were involved for data gathering for the same reason. Data was searched from scientific literature and reports of global organizations.

SLCA modelling was executed by using open LCA modelling tool. No existing databases were utilized. Weidema's version of QALY (aka WELBY) was used as impact assessment method. All data and severity weights were searched and calculated and added to the modelling tool. Modelling was done according to ISO 14040 and ISO 14044 standards and SLCA guidelines by Life Cycle Initiative (2020).

Traditional impact pathway was chosen as the approach of this study since it was considered the most suitable way to assess long term social impacts including socio-economic and biophysical indicators. Impact pathway is a consequential approach. Human wellbeing was chosen as AoP.

Following impact categories were included in the study:

- Occupational accidents
- Occupational diseases
- Diseases in local community
- Child labour
- Children out of school
- Compensation
- Excessive work
- Fair wage
- Gender related participation restrictions
- Inadequate access to health care
- Inadequate access to pensions or social security
- Interpersonal or communal violence
- Refugees or internally displaced
- Stressful working conditions
- Threats of violence or other contact crimes

Only diseases that are directly caused by cobalt mining were included. These are silicosis, lung cancer, birth defects, malaria and HIV. Other included health related indicators that were recognized in literature review were heavy alcohol consumption and drug abuse. Non-communicable diseases that are caused by multiple factors e.g. genetics or presence of other trace elements or compounds are excluded due to lack of data. HIV and malaria were recognized as significant communicable diseases related to ASM communities. In addition, neonatal conditions (birth defects), malaria, HIV and chirrhosis of the liver, which can be associated with heavy alcohol consumption, have significance due to being among top ten leading causes of death in low-income countries (WHO 2020b). Other health impacts and prevented social sustainability impacts e.g. health impacts due community development recognized in the literature review were excluded due to lack of data. Activity variables suggested by Life Cycle Initiative (2020) or weighting were not used.

The impacts of the LSM mining operations and impacts to local community were allocated between cobalt and copper by mass, when necessary. It was assumed that artisanal workers mined heterogenite and therefore there was no need for allocation in ASM.

The deviances considering completeness and consistency that may affect the end results are assessed as part of the discussion. The completeness and consistency are reviewed as recommended by Life Cycle Initiative (2020). Data quality was assessed according to pedigree matrix. The results are presented in the appendix 7.

5.2 Inventory analysis

Inventory data was collected based on the figure 2. Boxes marked with green color are included in the study. Orange boxes are indicators presented by Weidema (2006) that were classified as not relevant considering this study. Yellow color presents inventory indicators that might have impacts, but due to lack of data they could not be included. Blue boxes in the left corner of the figure are impact indicators introduced by Life Cycle Initiative (2020) which the author would have liked to connect to the model, but the implementation was too challenging due to lack of existing severity weights. The results were calculated for annual cobalt mining activity and then scaled per 1 kg of pure cobalt.

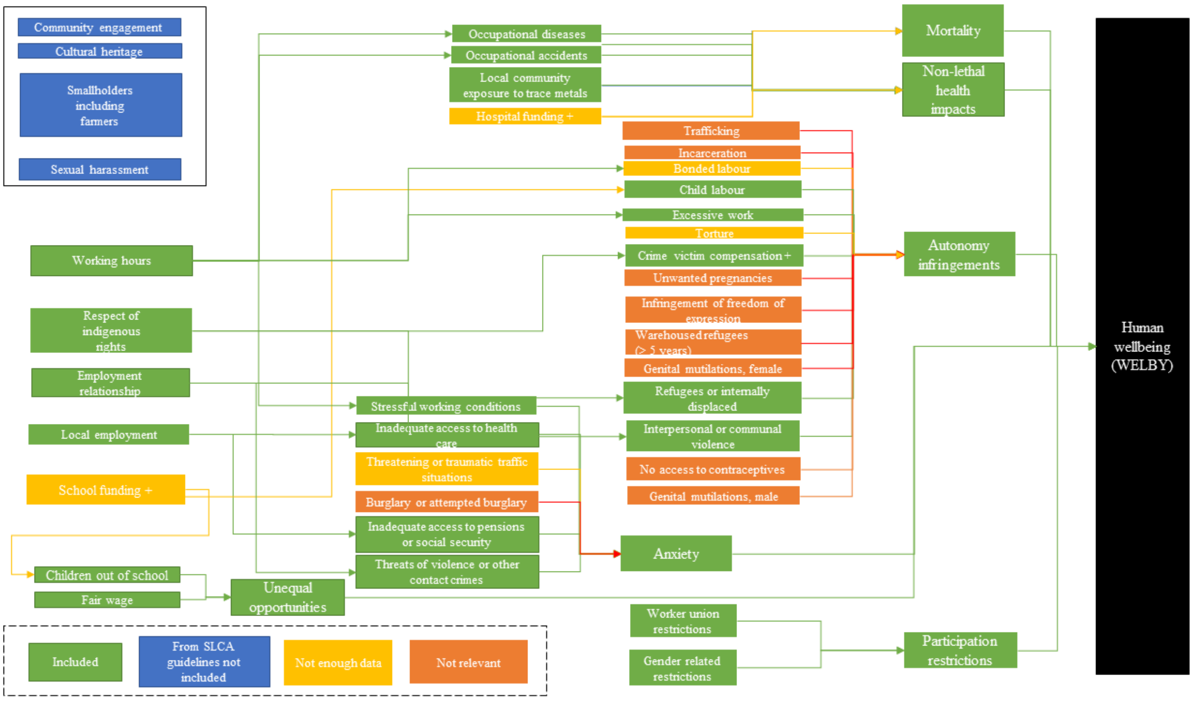


Figure 2. Indicators related to included stakeholder groups and WELBY methodology

Due to clarity for now all impacts are referred as DALY instead of WELBY or QALY since the calculations before endpoint indicator (QALY) are measured as DALYs. Weidema's implementation of QALY is referred as WELBY. The social sustainability impacts in DALY (WELBY) indicator are calculated by adding life years lost due mortality and years lived with disability affecting wellbeing together. Following equations were used to calculate impacts based on inventory data:

$$DALY = YLL + YLD$$

$$YLL = t_{exp} - t_{death}$$

$$YLD = w * D$$

Where YLL is years of life lost, YLD is years of life disabled, t_{exp} is expected age in population, t_{death} is actual age of death, w is severity weight and D is time duration of the disability. (Life Cycle Initiative 2020) Everything except severity weights is expressed in years. Severity weights are based on reviews on how much a certain disability affects human wellbeing. Disabilities can be put to scale on how much more likely people would prefer having one condition over another if they could choose e.g. between amputated toe and malaria. (WHO 2003)

DALY calculations are usually done by assessing different stages of diseases and mortality in different age groups. In this study the model was simplified using the average age the disease occurred and average time before mortality.

There is not one correct way to calculate DALYs even though it is often implemented as in disease of burden studies (Park et al. 2019). In this study, the prevalence data of different disabilities was used as a base for the calculation mainly due to availability reasons. However, the prevalence data for different stages of diseases were not available. The different stages were assessed by dividing the duration of stage by the life expectancy thus calculating the share of life stakeholders experienced disability. Allocated to the mining activity by multiplying it with the share of life the stakeholders were exposed to mining activity e.g., 42,7/60,7 years in case of adult workers. The resulting DALY was divided by annual cobalt production concerning the stakeholder group. Often DALY's are calculated for certain time period e.g., year 2000 (Park et al. 2019), but in this case the disabilities occurring during stakeholder's life related to cobalt mining is calculated per kg of cobalt. It could be thought that all the workers started working at the same time at the same age and during their lifetimes they experienced different disabilities and early death due to their profession of choice, which were added together when reaching their life expectancy. Since WELBY methodology has not been implemented in real life case before it is difficult to assess the optimal way to assign the different impacts in relation to 1 kg of cobalt.

Durations of different disabilities are presented in Appendix 4. It was assumed that all other wellbeing effect were annual except short-term effect related to injuries. In addition, it was assumed that all workers work till their death since there is no proper social security system to enable retirement.

Inventory data is presented in table 1. Reference data and more specific inventory data are presented in appendices 2 and 3. SLCA processes are described in detail in next subchapters. All impact categories mentioned in goal and scope definition are considered in all processes relevant to the stakeholder group, but if the result is considered as 0 based on the literature review the description may have been left out.

TABLE 1. Inventory data (life years /kg cobalt)

Inventory by process			
Flow	DRC: Cobalt mining ASM	DRC: Cobalt mining community	DRC: Cobalt mining LSM
AIDS with mild anemia		2,30E-05	
Alcohol problem use	8,60E-04		
Amputation of finger, thumb or toe			1,52E-07
ASM pit manager		1,41E-04	
ASM worker		1,42E-03	
Burns of <20% total surface area without lower airway burns: short term, with or without treatment			2,15E-07
Child labor	3,64E-05		
Children out of school		2,25E-03	
Crime victim compensation		1,07E-04	
Excessive work	1,89E-03		1,06E-04
Foot pain moderate			1,26E-05
Fracture of patella, tibia or fibula, or ankle: short term,with or without treatment	1,53E-05		
Fracture of radius or ulna: short term, with or without treatment	2,82E-05		
Gender related participation restrictions		4,27E-03	
General fracture			3,98E-07
Headache: tension-type	1,67E-03		
Hearing loss: mild	4,96E-04		3,48E-05
Hip pain moderate			1,51E-05
HIV/AIDS cases, receiving ARV treatment		9,11E-04	
Inadequate access to health care	1,89E-03	2,09E-04	
Inadequate access to pensions or social security	1,89E-03	2,09E-04	
Injury to eyes: short term	4,97E-04		
Interpersonal or communal violence	3,21E-05	7,36E-04	
Knee pain moderate			4,52E-05
Labor union restrictions	1,89E-03		
Low back pain, moderate	1,72E-03		8,79E-05
LSM pit manager		1,92E-05	
LSM worker		1,94E-04	
Lung cancer metastatic	1,38E-06	2,39E-07	7,72E-08
Mild silicosis	9,95E-05	1,38E-06	5,56E-06
Moderate hearing loss	1,19E-04		8,36E-06
Moderate malaria		1,60E-03	
Moderate silicosis	2,89E-05		1,57E-06
Mortality	7,89E-06		1,45E-08
Muscoskeletal problems upper limb pain moderate	3,10E-04		9,04E-05
Neck pain moderate			5,02E-05
Open wound: short term, with or without treatment	3,58E-04		6,44E-07
Other drug use disorders	1,45E-03		
Other injuries of muscle and tendon			2,00E-07
Other musculoskeletal disorders severity level 1 (Leg pain)	6,89E-04		
Poisoning: short term, with or without treatment	8,87E-05		
Refugees or internally displaced		1,07E-04	
Severe hearing loss	4,63E-05		3,25E-06
Severe motor plus cognitive impairment with blindness		1,05E-06	
Severe silicosis without heart failure	8,69E-07		
Skin irritation	1,61E-04		
Stressful working conditions	1,89E-03		1,06E-04
Symptomatic HIV with mild anemia		4,28E-04	
Threats of violence or other contact crimes	1,89E-03	1,19E-03	
Yll Birth defects		3,59E-05	
YLL HIV		2,04E-04	
YLL Lung cancer	3,05E-05		1,63E-06
YLL Malaria		7,02E-04	

5.2.1 ASM worker process description

The model was created by connecting impact indicators, which are then calculated as life years lost and years lived disabled, to impact categories presented by Weidema (2006). The included indicators and categories in ASM worker process are presented in the figure 3.

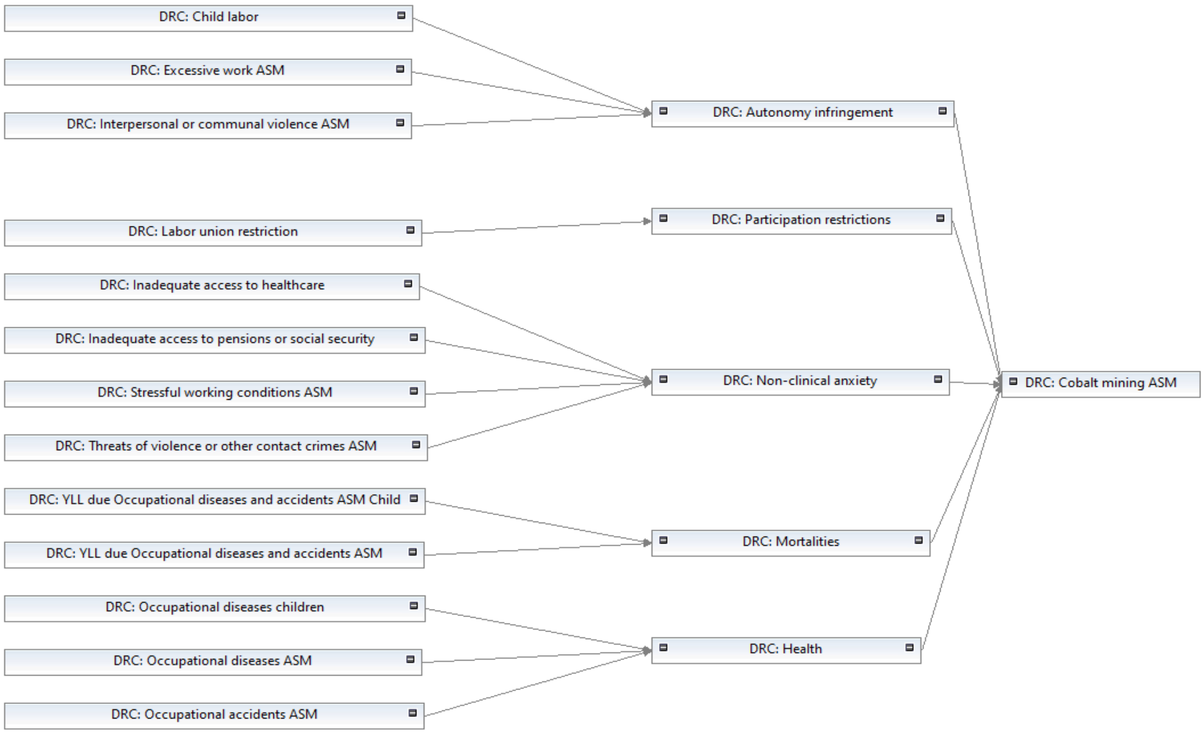


Figure 3. Indicators and categories concerning ASM worker process

The annual ASM cobalt production in this study was chosen to be 19 000 tons (CRU 2018;). It was assumed that 255 000 workers of which 35 000 were children worked annually in ASM mining (Kara 2018). There were several lower estimations of the number of ASM workers, but this was selected, because it was most recent, and the author had searched and visited all possible mining areas instead of just estimating the number. It was assumed that ASM worker worked 12 hour per day without vacation days (Amnesty International 2016).

5.2.1.1 Occupational health

Occupational diseases of ASM workers were assessed in this SLCA model. Banza Lubaba Nkulu et al. (2018) suggested that the studies concerning health consequences of ASM cobalt mining in DRC should include birth defects, neurodevelopmental impairment, respiratory disorders, heart and kidney disease and cancer. However, there were not enough data considering other impacts than respiratory effects and birth defects.

Mortality in mining accidents was assumed to be 0,5 % annually in ASM (Tsurukawa 2011). According to multiple studies ASM workers experienced most accident at the age of 20-30 years. 25 years was set as the average age of accident. (Elenge et al. 2013; Kyeremateng-Amoah & Clarke 2015)

The injuries and occupational hazards in ASM sector were assessed based on the studies by Elenge et al. (2013; 2010). All impacts from those studies were included except for cough, which is associated with silicosis and modelled separately. It was assumed that 60 % of the workers were diggers and rest of them were washers and crushers. It was assumed that workers started working at the age of 18 and were exposed to injuries for the rest of their working life, which is 40,7 years. Hearing loss was modelled according to Saunders et al. (2012) as cited in Basu et al. (2015). The rate of different types of hearing loss was based on Gyamfi et al. (2015). In that study the prevalence of hearing loss was studied at certain time point. Since hearing loss can develop multiple ways and different severity stages e.g. due to short or long time exposure there were not enough information available to build a disease model. Therefore, it was assumed that the certain time point expressed the annual share of different severity stages (WHO 2018) (figure 4).

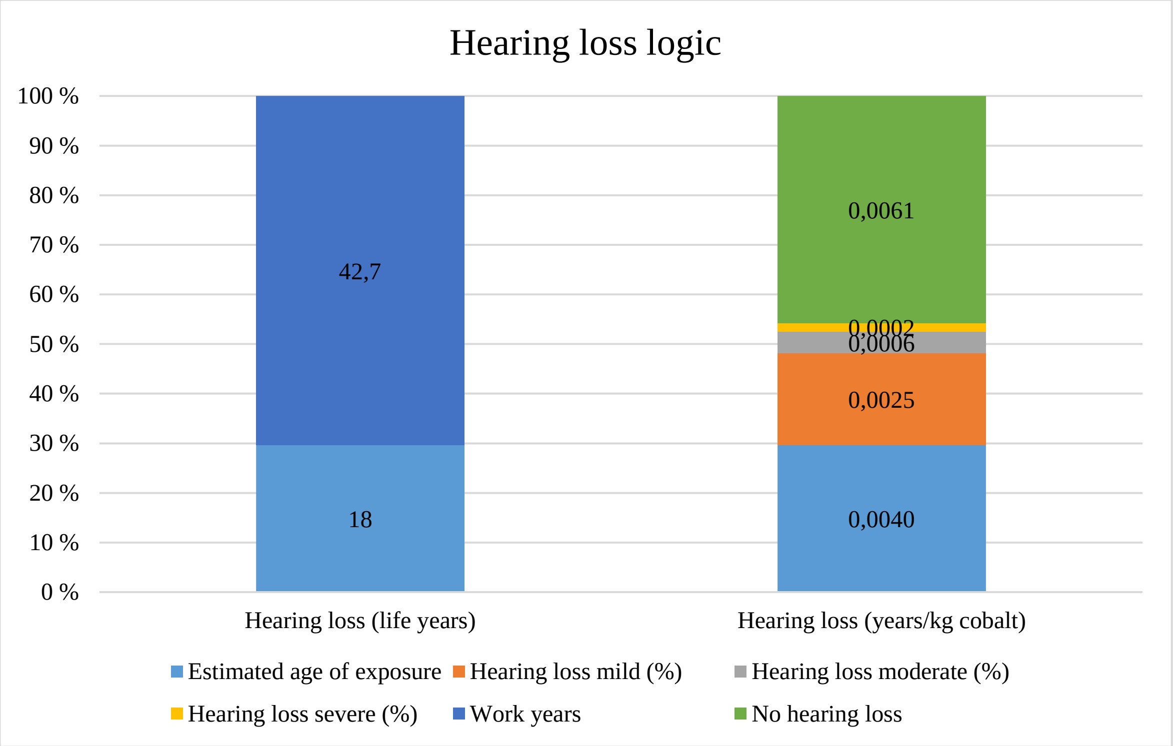


Figure 4. Annual prevalence is allocated to 42,7 years of work. years/kg of cobalt expresses the results in same scale.

Since child workers were recognized to be more vulnerable against health impacts and since they started their working life earlier compared to adults, they were modelled differently in some health categories. It was assumed that they started working at the age of 12, when considering silicosis and lung cancer. It was assumed that children did not work in the tunnels, before turning 18 years old and therefore were not exposed to occupational injuries. However, they were affected by nausea/copper poisoning (30 %), vision impairments and eye pain (25 %), skin irritation (34 %) and body pain (87 %). (World Vision 2013, 28)

Silicosis is modelled based on Yang & Yang (2006). The 3 stages of silicosis and their durations are presented in the figure 5. Since the average life expectancy is only 60,7 years it is assumed that the silicosis never reaches stage III in adult workers and no life years are lost due to silicosis (World Bank 2019a). Children workers reach the stage III before the life expectancy is reached (figure 5). The disease model presents how many percent of the silicosis cases develops to next stage (appendix 6).

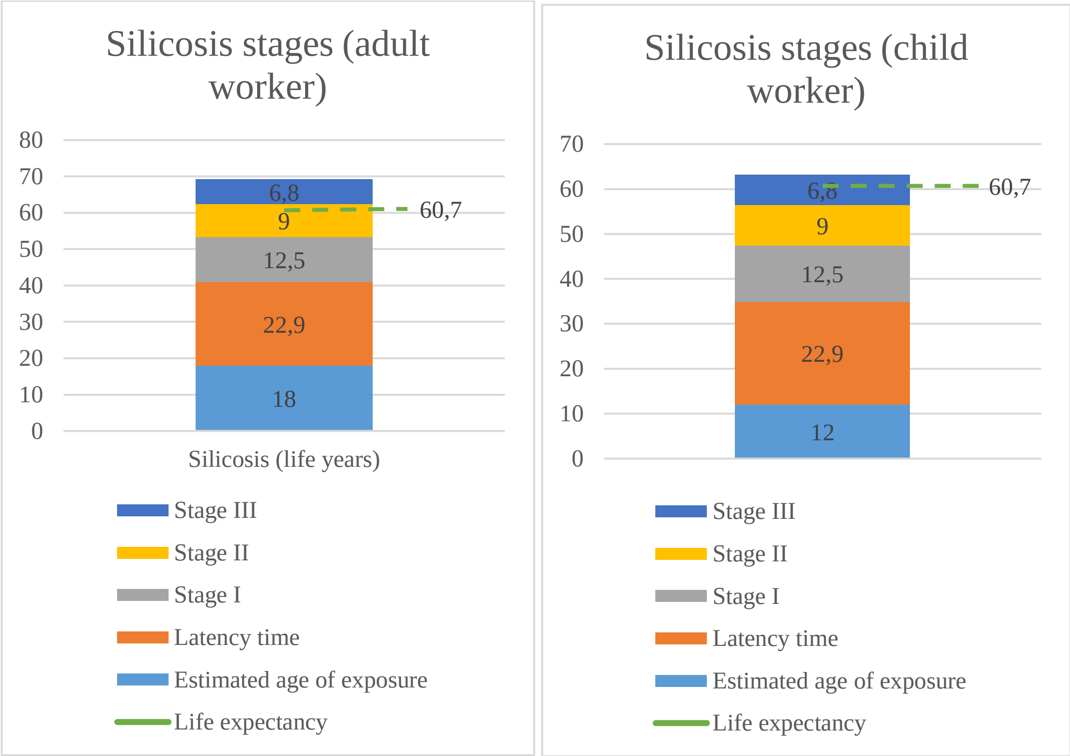


Figure 5. Development of silicosis in life years

Lung cancer was modelled according to an assumption that silica dust exposure caused 1,5 more lung cancer deaths compared to normal population (TTL 2021). The probability for normal population to get a lung cancer was estimated to be 1/16 as an average of different probabilities for male and female (American Cancer Society 2021). The latency time of lung cancer was estimated to be 22,8 years (Tae-Woo et al. 2010). It was assumed that average survival time was 1 year (Wabinga et al. 2011; Chokunonga et al. 2011). It was also assumed that the survival rate was 0 since the miners are poor and can’t afford expensive treatment. It was based on the studies conducted in Uganda and Zimbabwe in late 1990’s (Wabinga et al. 2011; Chokunonga et al. 2011). There were no recent cancer survival studies available from areas similar to DRC. Based on a study by Mielke et al. (2018) it was assumed that 50 % of workers that has lung cancer also had silicosis. If worker had both silicosis and lung cancer it was assumed that the cause of death was lung cancer. This is to avoid double counting related to co-morbidity (McDonald et al. 2020).

It was assumed that 52,8 % of the workers were great consumers of alcohol and 89 % used benzodiazepines or other drugs. (Elenge et al. 2013) It should be noted that benzodiazepine is normal prescription drug used to treat anxiety and insomnia, but it is also commonly abused due to its narcotic effect (Schmitz 2016). It is not clear which is the case in study by Elenge et al. (2013), but as literature review revealed drug abuse exist in among ASM workers.

5.2.1.2 Violence

It was assumed that 1,7 % of the ASM workers faced violence, but the threat of violence affected everyone. The 1,7 was based on the share of people being subject to physical assault annually in general in Lualaba province (UNICEF 2019).

5.2.1.3 Child labor

The short-term effect of child labour was assessed as part of ASM mining process, but the long-term effect which were caused by lack of education were assessed in local community process together with other children that did not have possibility to participate school. It was assumed that average age for children to start working was 12 years (World Vision 2013) (figure 7). The duration of child labour was set to 6 years after, which the child was 18 years old, and it was considered normal work. The long-term damage e.g. reduced income was considered to last the whole adult life of the child worker (Weidema 2006).

5.2.1.4 Excessive and stressful work

ASM was considered considered as excessive work by the definition of ILO (2021b) since there are no vacation days and the working days are 12 hours a day in ASM (Amnesty 2016). Mines has been recognized as stressful working environments (TTK 2015) and it was assumed that all ASM workers experienced stress.

5.2.1.5 Other autonomy infringements

It was assumed that ASM workers, even if they belonged to the worker union, did not have power to collective bargaining (World Vision 2013). It was assumed that ASM workers did not have good access to healthcare or any social security or pension (Office of Retirement and Disability Policy 2019).

5.2.2 LSM worker process description

The included indicators and categories in ASM worker process are presented in the figure 6. Other impacts were also assessed but were left out as the impact was considered as zero.

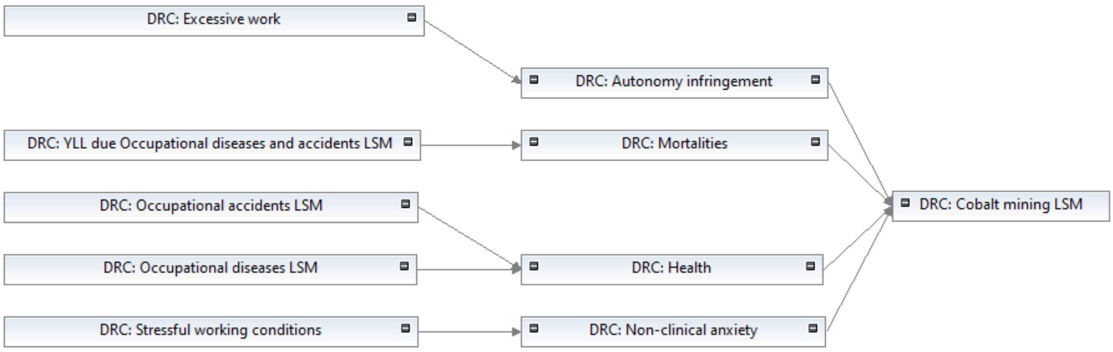


Figure 6. Indicators and categories considering LSM worker process

The annual LSM cobalt production was 80 000 tons (CRU 2018). Part of the impacts of LSM cobalt production were allocated to copper by mass, which was 14 000 000 tons. (NS Energy Group 2021) The number of LSM workers were estimated to be 30 000 (Respondent 5). The LSM workers were assumed to work 10 hours a day without any vacation days (Respondent 4).

5.2.2.1 Occupational health

Occupational diseases caused by vibration in LSM were modelled based on Jeripotula et al. (2020). Due to lack of severity weights shoulders, elbows, hands and upper back were combined under one indicator: upper limb muscoskeletal problems. All vibration induced diseases were assumed to cause moderate disability.

It was assumed that LSM workers were exposed to silica even though they used protective equipment. Silicosis and lung cancer were modelled similarly to ASM process.

The mortality in occupational accidents were assumed to be 0,0071 deaths per 1 000 000 working hours in LSM. It was assumed that the lethal accidents happened, when the stakeholder was 38 years old on average. This was based on the age group of 38-47 experiencing most accidents. The previous age group also experienced high amounts of lethal accidents, whereas the number of accidents was significantly reduced in the next age group, which is why 38 was seen as most suitable age to be usen in the study. (Stemn 2018). Annual mortality was calculated based on that and the assumption that LSM workers worked 10 hours/day and 365 days/year.

5.2.2.2 Other impacts

It was assumed LSM requires excessive work since there are no vacation days and the working days are 10 h a day in LSM (Respondent 4). Mines has been recognized as stressful working environments and it was assumed that mine work caused stress to all LSM workers (TTK 2015).

It was assumed that LSM workers had negotiation power due to worker unions since they work on contract. LSM workers were estimated to have access to healthcare and social security/pension due to new social security system and hospitals built by mining companies.

5.2.3 Local community process description

The inventory data for local community was based on the Kolwezi municipality data since it is built due and around cobalt mining industry. The population of the municipality is 500 000 people. The annual cobalt production is 17 000 tons and annual copper production 234 000 tons (Le Bec and Banda 2020). Respiratory health impacts were allocated to copper and cobalt by mass because the environmental pollution is due the whole mining industry. Other impacts were allocated for cobalt only. The included indicators and categories in ASM worker process are presented in the figure 7.

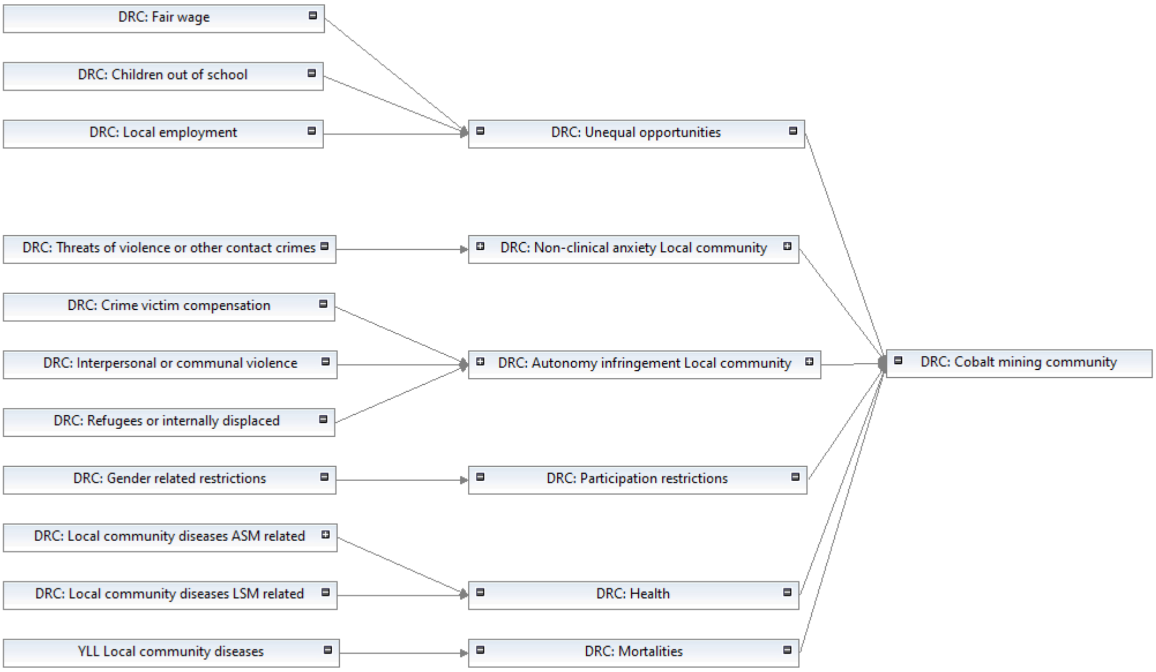


Figure 7. Impact indicators and categories considering local community process

5.2.3.1 Health

Local community exposure to hazardous amounts of trace metals was calculated by modelling number of people living near mines. It was assumed based on the studies by Banza Lubaba Nkulu et al. (2009;2018) that people living less than 3 km from area would be in danger to get health effects due to mining dust. Therefore, number of people living less than 3 km from Kamoto mining area in Kolwezi was modelled. It was estimated that 1/3 of the 500 000 residents of Kolwezi live less than 3 km from mine. It was assumed that local community was less exposed to the silica compared to mine workers and therefore the latency time for silicosis and lung cancer was longer both diseases occurring at the age of 60 (McCormack & Schüz 2011). Since the life expectancy was 60,7 years no YLL was caused by lung diseases (World Bank 2019a).

The definition of mining community is difficult. In a study conducted by Faber et al. 2017 mining community was defined as community, which closest border is maximum of 5 km from mine. It was also studied that 90 % of the miners live within 5 km of the mine and 100 % withing 10 km of the mine. Based on these definitions Kolwezi, which border starts directly from the mining cite and the furthest point is less than 10 km from the mine is defined as mining community. Following health impacts are calculated based on the population of Kolwezi.

Birth defects were modelled based on Vaan Brusselen et al. (2020). The normal incidence of birth defects was subtracted from the incidence precented in the study.

Malaria was modelled based on Basu et al. (2015). The age of death caused by malaria was set to 5 years since majority of the malaria deaths happen to children under 5 years old.
HIV patients is another malaria vulnerable group, but it is assumed that their deaths are consequence of HIV instead of malaria. (WHO 2021a)

HIV was modelled subtracting the normal prevalence of HIVin DRC (0,8 %) from the assumed prevalence of the HIV in mining areas (7%) (GSS 2013 according to Schwartz et al. 2021; UNAIDS 2021). It was assumed that HIV cases were caused by mining camp lifestyle and the average age of getting HIV was 20 years and average age of death was 33 years for 13 years is average lifetime after getting HIV without treatment (figure 8). It was assumed that the symptoms of HIV started after 5 years after getting the infection since it often takes several years for the symptoms to occur. (National institutes of Health 2020) It was assumed that 74,5 % of the patients received treatment thus not dying prematurely (appendix 6) (UNAIDS 2021). In other words, it calculated followingly:

$$Overall\ incidence\ burden\ cause\ x\ probability\ of\ transition\ to\ health\ state$$

(Devleesschauwer et al 2014).

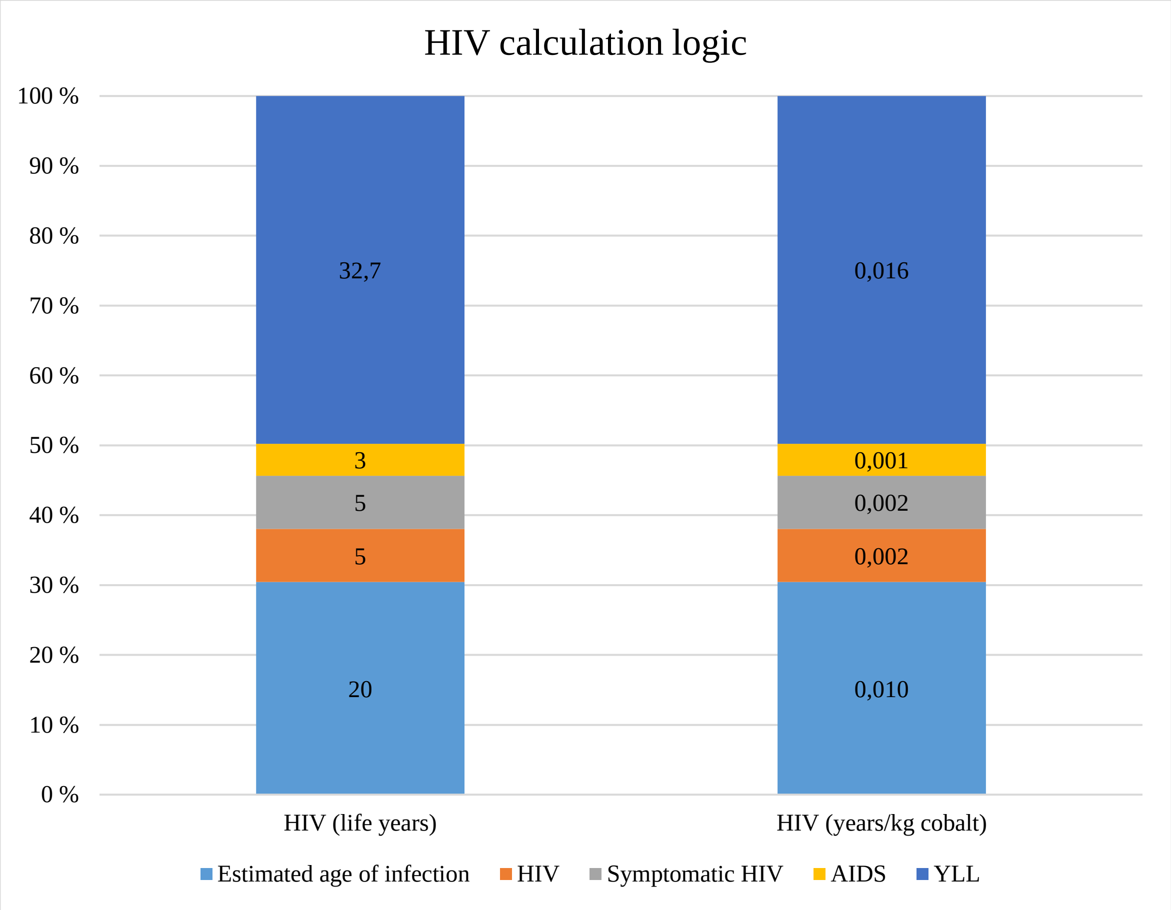


Figure 8. Stages and duration of HIV infection

5.2.3.2 Violence

It was assumed that 65 % of the children whose parents worked in ASM were subject to or threatened by violence due to ASM mining or its social consequences e.g. substance abuse to their parents. It was assumed that every family had 10 children. It was assumed that all women living together with ASM digger faced violence or were threatened by it. (GSS 2013 according to Schwartz et al. 2021) These were modelled using national number of ASM cobalt workers and annual national ASM cobalt production. It was assumed that all diggers were men and 60% of ASM workers were diggers (Elenge & De Brouver 2010).

5.2.3.3 Fair wage

Fair wage was calculated by comparing minimum living wage and normal consumption to wage earned by workers. Minimum living wage is based on the average family size, which is 10 in cobalt mining provinces (MPSMRM 2014). Monthly minimum living wage for 10-

person-family is calculated based on the basic expenditure basket by World Food Programme (2020) for 6 people in DRC. Fairwage calculation was based on the survival minimum expenditure basket, which was 109,62 USD. It is assumed that there are two parents is the family and both are working in ASM. Child work is not included in fair wage calculation. It was also assumed that 9 % of the ASM and LSM workers were pit managers (Geenen et al. 2021). As an exception fair wage was calculated using number of workers in DRC and annual national cobalt production. Fair wage is described in more detail in next chapter.

5.2.3.4 Inequality

Inequality in working in mining industry and in participation faced by women, because their gender was also studied. It was assumed that women lacking access to jobs at mining site, better paid mining jobs and ability to influence decision making concerning mining activity and community development projects experienced unequal opportunities. It was assumed that all women in Lualaba province in age group of 15-64 years faced inequality due to participation restrictions concerning mining activity. About 25,6 % of the DRC population is 15-64-year-old women (United Nations 2019). Gender inequality was calculated using national scale data instead of Kolwezi data.

5.2.3.5 Local employment

The local employment was calculated by estimating the amount of non-local workers and calculating social impacts that could have been avoided if local were employed in LSM mining. Following indicator were considered: inadequate access to healthcare and inadequate access to pension/social security. It was assumed that 98 % of the 30 000 LSM workers were not originally from local communities, but from other parts of the DRC (Respondent 8). Gender inequality was calculated using national scale data instead of Kolwezi data.

5.2.3.6 Children out of school

The loss of education and future salary due to children being out of school was calculated by using the long-term child work severity weights by Weidema (2006). It was assumed that 33,5 % of children aged 6-18 years (Unicef 2019, 242, 245, 248) were not able to attend to school in Kolwezi municipality mainly due to the financial effects caused by mining activity e.g. loss of income from traditional livelihoods. The percentage of children out of school was calculated as average of children being absent in different educational stages in Lualaba province. The age group presents 33,5 % of the total population (United Nations 2019). The impact of children not being able to attend school was based on them earning less money compared to more educated people when they entered working life at the age of 18.

5.2.3.7 Forced migration

Based on the two forced migration cases that were only ones recorded during last 10 years. The number of forcefully migrated people were allocated for 10 years the annual number of evicted people being 10600. It was assumed that all evicted people were compensated. (Kannah 2019; Amnesty International 2019) Eviction and compensation were calculated using national data instead of Kolwezi data.

5.3 Impact assessment

There was not any suitable set of impact indicators that could have been used alone to include all selected indicators. Literature was searched to find additional severity weights. Severity weights were added to open LCA impact assessment methods instead of social indicators, which were not suitable for impact pathway modelling.

The inventory data was divided into different categories using WELBY characterization model. The WELBY is calculated by estimating the share of people being affected by the different social impacts. The impacts are calculated at a scale from 1 to 0. One being one full life year with full life quality and zero being death. Negative values are considered worse than death. For example, being subject to torture can be considered worse than death. Results are divided into different categories and subtracted from full wellbeing. (Weidema 2006)

Modelling is executed by using disability severity weights by GBD (2019) and Weidema (2006) (table 2-7). The severity weights for short time injuries by GBD (2019) are calculated assuming the actual duration of injury whereas the long-term impacts are annual. The severity weights are based on DALY method and the final QALY results are calculated by subtracting them from full wellbeing. The severity weights and categories are presented in following tables.

Mortalities can be caused by accidents and diseases. Mortalities are presented in table 2.

TABLE 2. Mortality

Mortality YLL		
Impact	Severity weight	References
Death	1	Weidema 2006; WHO 2003

Severity weight for non-lethal health impacts included in SLCA model are presented in table 3. Same severity weights are used in WHO's burden of disease studies (GBD 2019).

TABLE 3. Non-lethal health impacts (GBD 2019)

Non-lethal health impacts GBD 2019	
Flow	Severity weight
AIDS with mild anemia	0,583
Alcohol problem use	0,115
Amputation of finger, thumb or toe	0,007
Burns of <20% total surface area without lower airway burns: short term, with or without treatment	0,016
Foot pain moderate	0,079
Fracture of patella, tibia or fibula, or ankle: short term,with or without treatment	0,05
Fracture of radius or ulna: short term, with or without treatment	0,028
General fracture	0,0111
Headache: tension-type	0,037
Hearing loss: mild	0,01
Hip pain moderate	0,079
HIV/AIDS cases, receiving ARV treatment	0,078
Injury to eyes: short term	0,054
Knee pain moderate	0,079
Low back pain, moderate	0,02
Lung cancer metastatic	0,451
Mild silicosis	0,019
Moderate hearing loss	0,027
Moderate malaria	0,051
Moderate silicosis	0,225
Muscoskeletal problems upper limb pain moderate	0,117
Neck pain moderate	0,114
Open wound: short term, with or without treatment	0,006
Other drug use disorders	0,116
Other injuries of muscle and tendon	0,008
Other musculoskeletal disorders severity level 1 (Leg pain)	0,023
Poisoning: short term, with or without treatment	0,163
Severe hearing loss	0,158
Severe motor plus cognitive impairment with blindness	0,625
Severe silicosis without heart failure	0,408
Skin irritation	0,011
Symptomatic HIV with mild anemia	0,277

Severity weights for autonomy infringements used in this SLCA model are presented in table 4. The long-term damage for child labor is used in assessing the inequality caused by lost income due lack of education caused by children not being able to attend school.

TABLE 4. Autonomy infringement

Autonomy infringement			
Infringement	Severity weight (Short-term damage)	Severity weight (Long-term damage)	References
Child labor	0,4	0,15	Weidema 2006
Excessive work	0,2	0	Weidema 2006
Interpersonal or communal violence	0,2	0	Weidema 2006
Crime victim compensation	-0,1	0	Weidema 2006
Refugees or internally displaced	0,3	0	Weidema 2006

Severity weights for indicators relating to non-clinical anxiety are presented in table 5.

TABLE 5. Non-clinical anxiety

Non-clinical anxiety		
Impact	Severity weight	References
Inadequate access to health care	0,09	Weidema 2006
Inadequate access to pensions or social security	0,09	Weidema 2006
Threats of violence or other contact crimes	0,09	Weidema 2006
Stressful working conditions	0,09	Weidema 2006

Severity weights modelled for fair wage are presented in table 6. Cookson et al. (2021) proposed that household consumption could be calculated similarly to health effects in scale from 1 to 0. One being standard consumption and zero minimum consumption. Severity weights were calculated using following equations by Cookson et al.:

$$w_{i,t} = h_{i,t} + u(c_{i,t}) - 1$$

$$u(i,t) = A - B * (C_{i,t})^{1-\eta}$$

$$A = c_{min}^{(1-\eta)} / (c_{min}^{(1-\eta)} - c_{std}^{(1-\eta)})$$

$$B = 1/(c_{min}^{(1-\eta)} - c_{std}^{(1-\eta)})$$

Where

- $w_{i,t}$ is period-specific wellbeing function (QALY)
- $h_{i,t}$ is health (QALY)
- η is elasticity of the marginal value of consumption
- c_{std} is standard consumption for good standard of living (USD)
- c_{min} is minimal consumption for a life worth living (USD)

c_{std} is set to 500 USD per month for 10-person-family was based on 500 USD being from the high end of the salaries paid for Congolese LSM workers (RAID 2019). c_{min} is based on the Survival Minimum Expenditure Basket (SMEB) by World Food Programme (2020), which is 109,62 USD/ 6 persons. The average family size is assumed to be 10 persons. It was assumed that there were two parents in the family one working as digger in mining and another in ore washing or farming earning 1 USD/day. The assumed wages for different worker categories were:

- ASM worker 90 USD/month (Amnesty International 2016)
- LSM worker 200 USD/month (RAID 2009)
- ASM pit manager 300 USD/month (estimated from BGR 2019)
- LSM pit manager 500 USD/month (RAID 2019).

Variable η was set to 1,26 based on the Cookson et al. (2021). Different from Cookson et al. it was assumed that health was one and health effects were not involved in the unequal opportunities disability weights since they are calculated separately. Severity weights were modified from QALY to DALY form by subtracting the result from 1.

TABLE 6. Fair wage

Unequal opportunities (Fair wage)		
	Severity weight	Reference
W_ASM worker	1,08	Cookson et al.
W_LSM worker	0,81	Cookson et al.
W_ASM pit manager	0,48	Cookson et al.
W_LSM Pit manager	-0,18	Cookson et al.

Severity weights for participation restrictions are presented in table 7. Weidema (2006) estimated the severity weight for participation restriction to be 0,1. In this study it was assumed that all participation restriction related severity weights were 0,1.

TABLE 7. Participation restrictions

Participation restrictions		
Impact	Severity weight	References
Labor union restrictions	0,1	Weidema 2006
Gender related participation restrictions	0,1	Weidema 2006

6 RESULTS

The results are presented in the table 8. Current level of wellbeing (2,85E-02) is the endpoint QALY for the cobalt mining in DRC. It is also expressed as percentage to better reflect the lost wellbeing. The result should not be interpreted as stakeholders being only 80,81 % alive, but as them experiencing their life being 80,78 % between life and death (WHO 2003). The full wellbeing of workers was calculated by dividing the annual number of workers by the annual cobalt production, which is first multiplied by share of working years of DRC's life expectancy. This is done in order to allocate the years spent disabled to 1 kg of cobalt since different disabilities occur at different time of life. The full wellbeing of local community is calculated by dividing population of Kolwezi with Kolwezi's annual cobalt production. All results are scaled based on the share of annual cobalt production followingly: ASM 0,2 kg, LSM 0,8 kg and local community 1 kg. Results of different processes are presented in Appendix 5.

TABLE 8. Results

Total results		
Impact	Total Damage	% of full wellbeing
Value of full well-being before impacts	3,15E-02	100 %
Mortality	9,82E-04	-3,12 %
Non-lethal health impacts	7,98E-04	-2,53 %
Autonomy infringements	5,88E-04	-1,87 %
Anxiety	8,34E-04	-2,65 %
Unequal opportunities	2,24E-03	-7,10 %
Participation restrictions	6,16E-04	-1,95 %
Current level of wellbeing due to cobalt mining	2,55E-02	80,78 %

Cobalt mining had largest impact on artisanal mine workers' wellbeing due to non-lethal health impacts and non-clinical anxiety. LSM workers had second most wellbeing impacts mostly caused by autonomy infringements and non-lethal health impacts. Local community had least wellbeing impacts suffering most from the unequal opportunities due to wage inequality. The results can be presented as total damage (QALY) or as percentage of full wellbeing. Since the full wellbeing per kg of cobalt is relatively small in ASM and LMS compared to local community due to less people being exposed, the results are presented in both forms for them to be easier to understand (figure 9). The share of ASM of the total wellbeing before impacts are subtracted is only 6,0 % and the share of LSM 0,67 %. The term total used in figure 9 means the total QALY of cobalt mining in DRC presented in previous table.

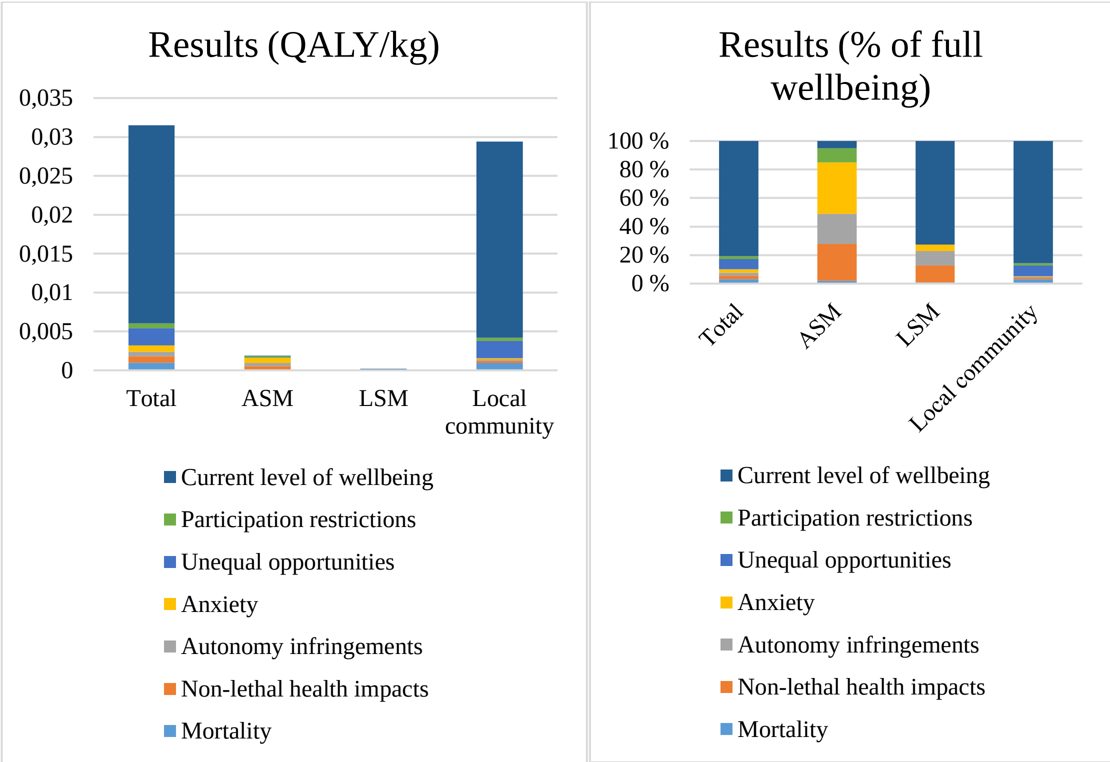


Figure 9. Total results and results per process as QALY and percentage of full wellbeing

The wellbeing of the ASM workers were reduced to 5,48% of the full wellbeing. The impacts considering ASM workers in DALY unit before they are subtracted from full wellbeing to produce QALY are presented in figure 10. Notable wellbeing impacts were caused by labor union restrictions in participation restrictions category. Non-clinical anxiety caused most impacts inadequate healthcare inadequate access to pensions and social security, stressful working conditions and threats of violence each contributing -9,0 % of ASM workers' wellbeing. Mortality was mostly caused by accidents. Alcohol problem use, headache and drug use caused largest non-lethal health impacts. Excessive work as autonomy infringement caused significant impacts.

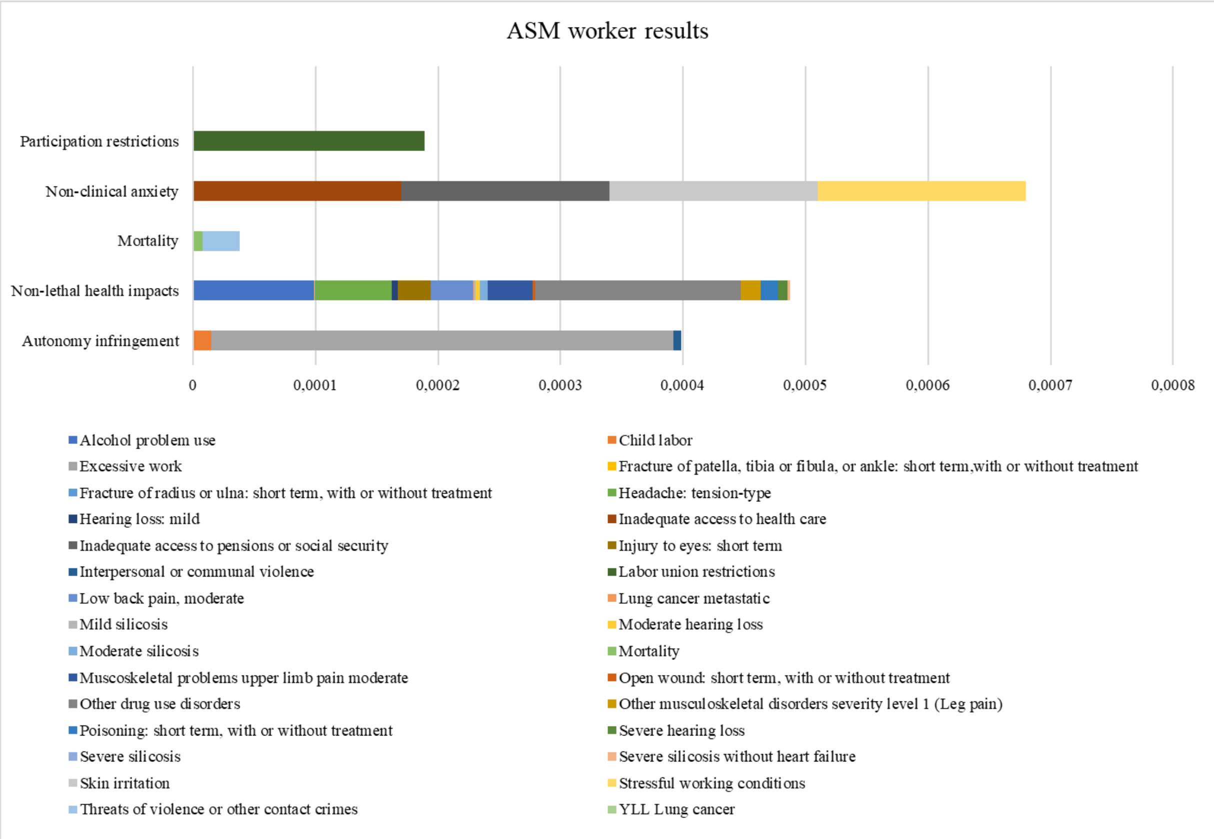


Figure 10. Results per flow considering ASM workers (DALY)

The results considering LSM workers are presented in figure 11. Stressful working conditions in non-clinical anxiety caused large health impacts. Life years lost due to lung cancer caused most mortality. The largest contributors in non-lethal health impacts were disabilities caused by whole-body vibration e.g., knee pain, low back pain, muscoskeletal problems, and neck pain. Largest single impact was caused by excessive work in autonomy infringement category, which contributed -10,0 of LSM workers' wellbeing.

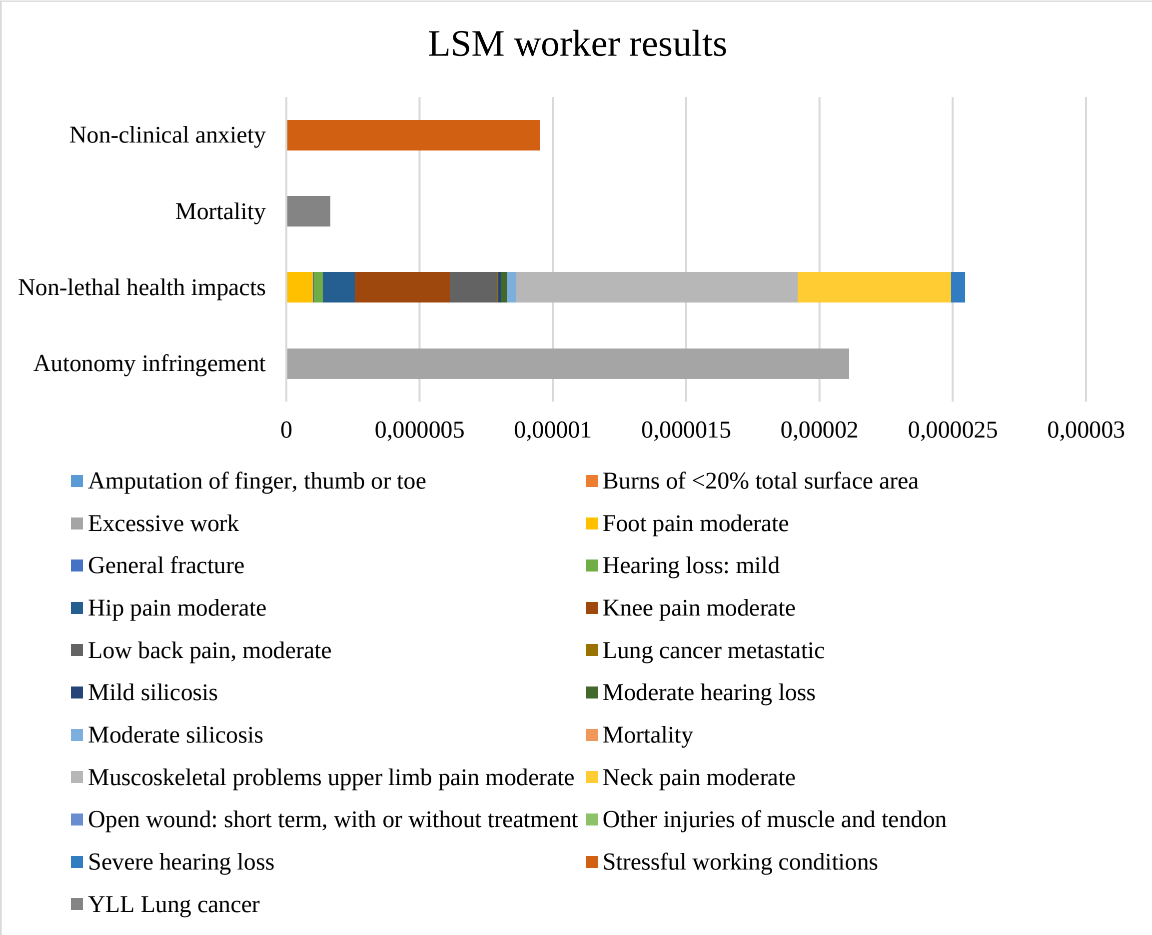


Figure 11. Results per flow considering LSM workers (DALY)

The results considering local community are presented in figure 12. Unequal opportunities was the largest category considering local community. Wage inequality faced by ASM workers was the largest contributor. Also, children not attending school and wage inequality faced by LSM workers caused significant wellbeing impacts in unequal opportunities category. Higher wage earned by LSM pit managers causes minor positive impacts. Gender related participation restrictions belonging to participation restrictions category caused significant wellbeing impacts. Threats of violence and other contact crimes was largest contributor in non-clinical anxiety category. HIV and Malaria caused most mortality and most non-lethal health impacts. Positive impacts were caused by compensation related to forced evictions in autonomy infringement category, but it did not compensate the internal displacement. Interpersonal violence caused most autonomy infringement.

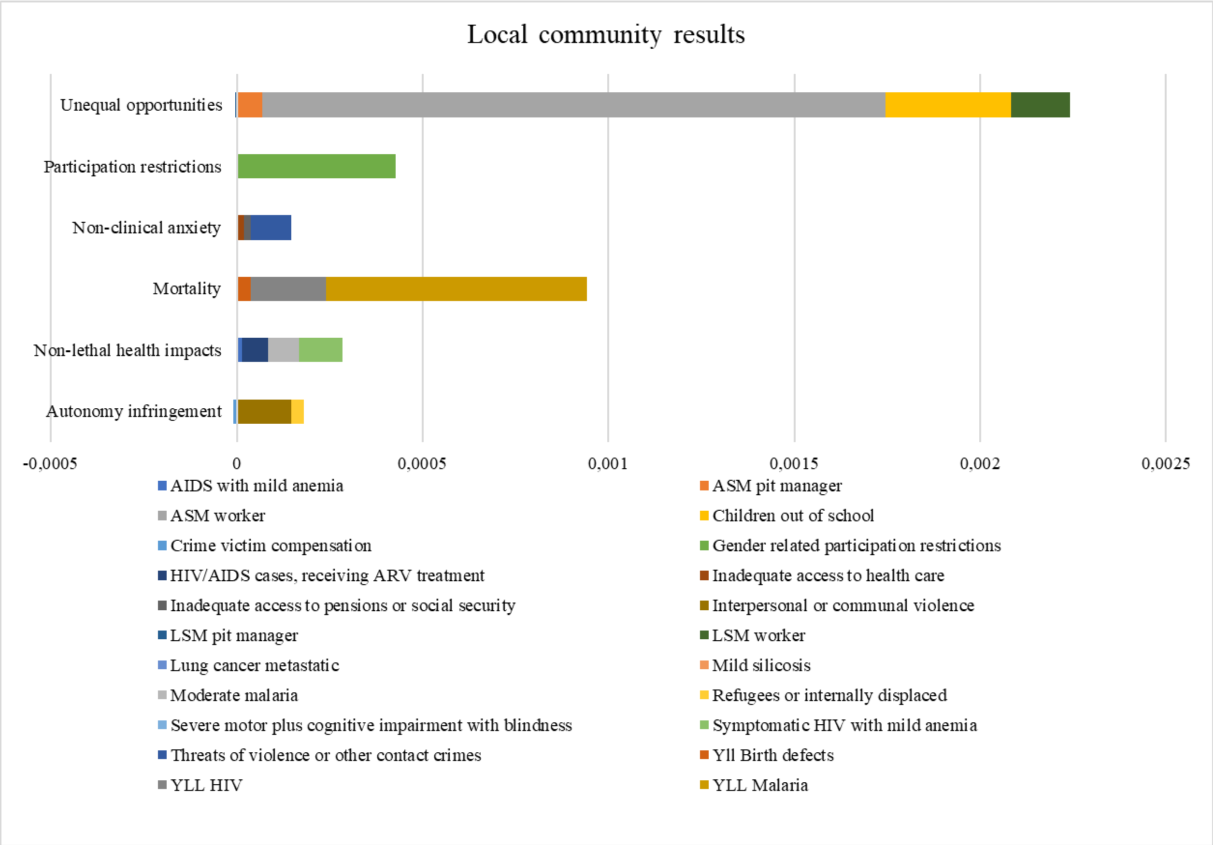


Figure 12. Results per flow considering local community (DALY)

7 DISCUSSION

In this Master's thesis two research questions were studied: how cobalt life cycle affects on social sustainability and what are the analytical possibilities and challenges of social life cycle assessment in a cobalt case study? The results are discussed in this chapter.

7.1 Impacts of cobalt value chain on social sustainability

The results imply that cobalt mining causes significant negative wellbeing impacts in DRC. Local community is the largest group experiencing negative wellbeing impacts, but ASM workers experienced most impacts, when compared to their potential full wellbeing. Non-clinical anxiety was largest category considering ASM workers. LSM workers experienced wellbeing impacts that are typical to industrial mining in general recognized by e.g., International Council of Mining and Metals (2021), which promotes sustainable development in mining industry. LSM workers experienced less negative wellbeing impacts than ASM workers. ASM workers suffered from participation restrictions, which affects their possibility to change the situation.

ASM and LSM workers are both also part of the local community. Therefore, their wellbeing reflects on the wellbeing of local community as well. The unequal wages earned by ASM workers had significant negative impact on the local community where as LSM pit managers earned enough to cause minor positive impacts. Many impacts considering local community could be traced back to ASM worker subculture e.g., violence caused by substance abuse and HIV due prostitution (Sovacool 2021; Hayes and Perks 2011).

All stakeholder groups suffered from early mortality and especially ASM and LSM workers also from health impacts. The life expectancy used in this study (60,7 years) was already low compared to highest life expectancy in the world, 85,1 years in Hong Kong. (World Bank 2019b). On the other hand, the life expectancy at birth in DRC was estimated for the people born in 2019, whereas the current young adult ASM workers were born in the early 2000's, when life expectancy at birth was e.g., 51,4 in 2002 (World Bank 2019a). Using the 2002 life expectancy would have reduced the health-related impacts since the lung diseases occur at older age. Then again if the life expectancy continues to rise the mine workers and mining communities will face more years lived with disability and lost life years compared to other population in DRC. This is since the life expectancy is still so low that diseases, like silicosis, does not have time to reach the most severe stake or cause YLL in adult ASM worker population. The topic is also discussed by McCormack & Schüz (2011).

Indicators recommended by the Life Cycle Assessment (2020) that were not included in this study were sexual harassment, cultural heritage, community engagement and smallholders e.g., farmers. In the literature review it was recognized that sexual harassment exist in mining communities and farming as a livelihood has become more difficult due to pollution originating from mines, but there were no studies available concentrating on those topics. Mining companies do engage local communities at least in superficial level, but the impacts were too difficult to track using only literary sources. Cultural heritage is also important, but the inclusion would require deeper knowledge of the culture. Many communicable diseases and toxic impacts of several trace elements recognized in the literature review were excluded from the study. Only two positive impacts could be added to the model, when larger implication of positive impacts is recommended. All the fore mentioned reasons may add uncertainty to the results. It should be noted that results are unlikely suitable for comparison with other product systems since it would require similar system boundaries and implementation of WELBY/DALY methodologies.

There are some previous SLCA studies considering cobalt or battery industry. A research paper was found where DALY was applied in a study considering tire studs including cobalt from DRC area using conflict victims as an impact indicator. The negative social sustainability impacts in upstream processes outweighed the positive impacts in use phase. (Furberg et al. 2018) Thies et al. (2019) studied the social sustainability impacts of LiB manufacturing using Social Hot Spot Database. The risk of social sustainability impacts in raw material extraction were notable in all studied categories: corruption, child labour and poverty and occupational hazards. The results considering extraction were same in scenario, where the manufacturing happened in China and in scenario, where it happened in Germany.

A case study considering ASM mining in DRC and SLCA was published recently. It concentrated on comparing impacts of responsibility sourcing initiatives to normal situation. Workers and local communities were included as stakeholder groups. Impact categories were based on the same SLCA guidelines as in this study, but the impact assessment method was more qualitative. The result of the study was that improvement had happened in several categories in sites, where initiatives where piloted. (Mancini et al. 2021) This gives hope that impacts negative impacts recognized in this study may be reduced.

7.2 Evaluation of social life cycle assessment as a research method

WELBY methodology was used as an SLCA method in this study. WELBY methodology gives results in QALY and as percent of full wellbeing. The results as percent of full wellbeing are easy to understand, communicate and interpret. In addition, comparison is always included in WELBY methodology since the full wellbeing used in result calculation presents the potential wellbeing of stakeholders without the impacts of studied phenomenon e.g., cobalt mining. Therefore, the results are always compared to a situation, where no impacts occur. The results in QALY are essential if the results were to be compared with another product system. The QALY also reveals, how large effect the different processes in product system have on the final impact e.g., in this study the ASM workers experienced most wellbeing impacts, but since their share of the full wellbeing was only 6,0 % the impact on the full wellbeing was smaller.

In this study SLCA was combined with literature review, which was recognized as good practice since it helped to acquire deeper knowledge on the subject. Similar approach was used by Mancini et al. 2021. Combining quantitative and qualitative data is typical to SLCA (Life Cycle Initiative 2020) and is considered as possibility since it better describes the related social mechanisms. In addition, it helps to reveal connections between different indicators, which is important considering impact pathway approach. As an example, the literature review revealed the connection between anxiety caused by dangers of ASM work and substance abuse and substance abuse and violence. SLCA and other sustainability related research methods are often used as a way to find improvement options (Life Cycle

Initiative 2020). Revealing connections between different impacts helps to find root causes, which is useful when trying to find the best target for improvements.

Since the 3 aspects of sustainability are interconnected and should be assessed as one, finding the most suitable SLCA method to enable sustainability LCA is important. WELBY or impact pathway in general as a methodology could work together with environmental and economic LCA. Health impacts and environmental pollution can be connected in theory. This approach was first tested during this Master's thesis process, but it failed due to lack of sufficient data. Economic data in the form of fair wage was included in this study. The modelled severity weights differed slightly from the other severity weights since they were scaled between minimum and normal consumption instead of experience of life and death. Using this kind of approach to combine social and economic sustainability impacts in LCA could be further studied.

One of the largest challenges considering execution of this study was data quality. Cobalt mining in DRC has been studied from many different perspectives before but finding quality data considering all included impact indicators was difficult. Therefore, the results of this study have many uncertainties as previously mentioned. Probably utilizing SLCA in less studied product system would require primary data collection. Also, use of primary data instead of secondary data is recommended in general (Life Cycle Initiative 2020), but it was not possible in this study.

In this study, the SLCA model relied on average life expectancy and average ages of where the different disabilities occurred instead of survivorship and wellbeing curves presented by Weidema (2006). The burden of disease study also calculates prevalence in different age groups (WHO 2018). This kind of approach would have been difficult to implement with the existing data. Further studies are required to find out if the approach used in this study is sufficient or does it cause too much uncertainty. Unless the burden of disease study can be somehow used as a base of the SLCA model, the use survivorship curve of different diseases will be a huge challenge.

Including positive effects in SLCA studies is recommended by Life Cycle Initiative (2020). In this case, the inclusion was challenging, because of the lack of data considering schools and hospitals funded by LSM companies as a demand of mining code. If that kind of data would have been available, the positive effect could have been estimated e.g., by using avoided health and lost income impacts. Including only negative impacts makes it difficult to assess the social sustainability impacts objectively.

Since the impact pathway methodology in general is not fully established yet (Life Cycle Initiative 2020), more development and standardization are required for the method to be more consistently applied in different studies. Consistency is needed to enable comparison between different SLCA studies, and it also helps the implementation of the method thus making it more appealing option in assessment of social sustainability impacts. DALY/QALY/WELBY methodologies lack currently severity weights considering multiple impact categories, which makes the inclusion of all impact indicators recommended by Life Cycle Initiative (2020) challenging. Also, the time allocation and its relation to prevalence and incidence in DALY-based methodologies can be executed in several ways impacting the results.

The aggregation of the results may have impacted the way they could be interpretated in this study. The results were aggregate based on the impact categories presented by Weidema (2006), which makes the flows that are interconnected scatter across different categories. If the results were aggregated based on their relationship with each other e.g., the anxiety-substance-abuse-violence case, the interpretation would be easier. However, this may make the modelling part more difficult.

8 CONCLUSION

This study shows that cobalt mining has significant negative wellbeing effects that concern ASM workers especially, but local community is also impacted in large quantities. Expanding mining activity due to increasing need for cobalt may cause more and more people being exposed to social sustainability impacts. Even though child labor is the impact often most present in the media the largest challenge seems to be the anxiety caused by the ASM work and its side effects. The wellbeing impacts experienced by ASM and LSM workers also reflect to the situation of local community.

Social life cycle assessment combined with literature review was used as a method in this study. Several challenges were faced during the modelling process. Finding the data fulfilling the requirements was difficult, which can make it challenging to apply this method in areas less studied. In addition, it is not sure if the implementation of WELBY method based on the average ages instead of wellbeing/survivorship curves is sufficient. The development and standardization of new severity weights considering WELBY methodology is recommended. Overall standardization of impact calculation would be helpful for implementation of the method. Better ways to aggregate the results could be considered.

Despite of the formerly mentioned challenges SLCA as a social sustainability measure seems promising and easily interpretable if there is enough data available. The combination of literature review with SLCA was recognized to be a good practice. There are also ways, at least in theoretical level, to combine environmental and economic data with WELBY methodology to assess the other aspects of sustainability.

9 SUMMARY

Fight against climate change requires system transition in mobility. More EVs also mean more batteries. The increasing number of batteries cause social sustainability challenges since more and more raw materials are needed and those are often mined in lower income countries.

The aim of this study was to find out about social sustainability impacts of cobalt mining in DRC by utilizing SLCA methodology and literature review. The results showed significant reduction in human wellbeing especially concerning ASM workers, but also among LSM workers and local communities. However, the share of ASM and LSM workers was minor of the total wellbeing. Different indicators were significant to different stakeholders. Anxiety and its side effects had largest impact on ASM workers. It was recognized that the wellbeing of different stakeholders is connected since workers are part of the local communities, and even their share of the total wellbeing is small, their wellbeing affects on the wellbeing of local communities on larger scale.

SLCA and WELBY methodologies require development, but both seem promising when modelling social sustainability impacts. Presenting results as percentage of full wellbeing makes them easily understandable. Including literature review as part of the SLCA is recommendable to get the full picture of the social consequences and mechanisms through value chain. The standardization of impact assessment methodology is recommended as is development of lacking severity weights.

REFERENCES

Adjei, A. Andrew, Brandful, James, Lurie, Mark, Lartey, Margaret, Krampa, Francis, Kwara, Awewura. 2014. Human immunodeficiency virus, syphilis prevalence and risk factors among migrant workers in Konongo, Ghana. Advances in Infectious Diseases, 4(3), 132– 141. [Retrieved August 8, 2021]. From: https://doi.org/10.4236/aid.2014.43020

Afrewatch. 2020a. Report of the Stakeholder Brainstorming Workshop on Artisanal Mining. [Retrieved July 6, 2021]. From: https://afrewatch.org/2731-2/

Afrewatch. 2020b. Affaires dangereuses dans un État défaillant Glencore en République démocratique du Congo. [Retrieved March 16, 2021]. From: https://afrewatch.org/affaires-dangereuses-dans-un-etat-defaillant-glencore-en-republique-democratique-du-congo/

Afrewatch. 2019. Rapport alternatif sur l'impact de l'exploitation minière sur les droits des femmes en République démocratique du Congo. [Retrieved March 16, 2021]. From: https://afrewatch.org/rapport-alternatif-sur-limpact-de-lexploitation-miniere-sur-les-droits-des-femmes-en-republique-democratique-du-congo/

Afrewatch. 2017. Sino-Congolaise Des Mines Facing the Challenge of the Millenium: How Sicomines deprived communities of their rights after polluting the environment. [Retrieved March 16, 2021]. From: https://afrewatch.org/the-sino-congolaise-des-mines-facing-the-challenge-of-the-millennium-how-sicomines-deprived-communities-of-their-rights-after-polluting-the-environment/

American Lung Cancer Society. 2021. Key Statistics for Lung Cancer. [Retrieved July 29, 2021]. From: https://www.cancer.org/cancer/lung-cancer/about/key-statistics.html

Amnesty International. 2019. DRC: Crisis in Mines Requires Sustainable Solution. [Retrieved June 1, 2021]. From: https://www.amnesty.org/en/documents/afr62/0772/2019/en/

Amnesty International. 2018. Bulldozed: How a Mining Company Buried the Truth About Forced Evictions in the Democratic Republic of the Congo. [Retrieved June 19, 2021]. From: https://www.amnesty.eu/wp-content/uploads/2018/10/Bulldozed_DRC_report.pdf

Amnesty International. 2017. Time to Recharge – Corporate action and inaction to tackle abuses in the cobalt supply chain. [Retrieved February 9, 2021]. From: https://www.amnesty.org/download/Documents/AFR6273952017ENGLISH.PDF

Amnesty International. 2016. This is what we die for. [Retrieved February 3, 2021]. From: https://www.amnesty.org/download/Documents/AFR6231832016ENGLISH.PDF

Arvidsson, Rickard, Hildebrand, Jutta, Baumann, Henrikke,Islam, K.M. Nazmul, Parsmo, Rasmus, Zamagni, Alessandra, Macombe, Catherine and Traverso, Marzia. 2018. A method for human health impact assessment in social LCA: lessons from three case studies. The International Journal of Life Cycle Assessment, 23(3), 690–699. [Retrieved March 16, 2021]. From: https://doi.org/10.1007/s11367-016-1116-7

ATDSR. 2013. Toxicological profile for uranium. [Retrieved July 8, 2021]. From: https://www.atsdr.cdc.gov/toxprofiles/tp150.pdf

ATSDR. 2012. Toxicological profile for manganese. [Retrieved July 8, 2021]. From: https://www.atsdr.cdc.gov/toxprofiles/tp151-p.pdf

ATSDR. 2005. Toxicological profile for nickel. [Retrieved July 8, 2021]. From: https://www.atsdr.cdc.gov/toxprofiles/tp15.pdf

ATSDR. 2004. Toxicological profile for copper. [Retrieved July 1, 2021]. From: https://www.atsdr.cdc.gov/toxprofiles/tp132.pdf

Banza Lubaba Nkulu, Celestin, Casas, Lidia, Haufroid, Vincent, De Putter, Thierry, Saenen, Nelly, Kayembe-Kitenge, Tony, Musa Obadia, Paul, Kyanika Wa Mukoma, Lunda Ilunga, Jean-Marie, Nawrot, Tim, Luboya Numbi, Oscar, Smolders, Eric and Nemery, Benoit. 2018. Sustainability of artisanal mining of cobalt in DR Congo. Sustainability of artisanal mining of cobalt in DR Congo. Nat Sustain **1,** 495–504 [Retrieved April 29, 2021]. From: https://doi.org/10.1038/s41893-018-0139-4

Banza Lubaba Nkulu, Celestin, Nawrot, Tim S, Haufroid, Vincent, Decrée, Sophie, De Putter, Thierry, Smolders, Erik, Kabyla Ilunga, Benjamin, Luboya Numbi, Oscar, Ilunnga Ndala, Augustin, Mwanza Mutombo, Alain and Benoit, Nemery. 2009. High human exposure to cobalt and other metals in Katanga, a mining area of the Democratic Republic of Congo. Environmental Research, 109(6), 745–752. [Retrieved March 8, 2021]. From: https://doi.org/10.1016/j.envres.2009.04.012

Baraza, Salim. DRC: A history of pillage, destination unknown. [Retrieved March 19, 2021]. From: https://www.theafricareport.com/47442/drc-a-history-of-pillage-destination-unknown/

Basu, Niladri, Edith Clarke, Allyson Green, Benedict Calys-Tagoe, Laurie Chan, Mawuli Dzodzomenyo, Julius Fobil, et al. 2015. Integrated assessment of artisanal and small-scale gold mining in Ghana--part 1: human health review. International journal of environmental research and public health. [Online] 12 (5), 5143–5176. [Retrieved June 19, 2021]. From: https://doi.org/10.3390/ijerph120505143

Battery University. 2019. BU-205: Types of Lithium-ion. [Retrieved June 20, 2021]. From: https://batteryuniversity.com/article/bu-205-types-of-lithium-ion

BBC. 2021. Dan Gertler - the man at the centre of DR Congo corruption allegations. [Retrieved June 1, 2021]. From: https://www.bbc.com/news/world-africa-56444576

Benoit, Nemery and Banza Lubaba Nkulu. 2018. Assessing exposure to metals using biomonitoring: Achievements and challenges experienced throughsurveys in low- and middle-income countries. Toxicology Letters, 298, 13–18. [Retrieved May 7, 2021]. From: https://doi.org/10.1016/j.toxlet.2018.06.004

BGR. 2019. Mapping of the Artisanal Copper-Cobalt Mining Sector in the Provinces of Haut-Katanga and Lualaba in the Democratic Republic of the Congo. [Retrieved March 8, 2021]. From: https://www.bgr.bund.de/EN/Themen/Min_rohstoffe/Downloads/studie_BGR_kupfer_kobalt_kongo_2019_en.html

BGR. 2019. Mapping of the Artisanal Copper-Cobalt mining Sector in the Provinces of Haut-Katanga and Lualaba in the Democratic Republic of the Congo. [Retrieved August 2, 2021]. From: https://www.bgr.bund.de/EN/Themen/Min_rohstoffe/Downloads/studie_BGR_kupfer_kobalt_kongo_2019_en.pdf?__blob=publicationFile&v=3

BGR. 2017. COBALT FROM THE DR CONGO – POTENTIAL, RISKS AND SIGNIFICANCE FOR THE GLOBAL COBALT MARKET. [Retrieved March 8, 2021]. From: https://www.deutsche-rohstoffagentur.de/DE/Gemeinsames/Produkte/Downloads/Commodity_Top_News/Rohstoffwirtschaft/53_kobalt-aus-der-dr-kongo_en.pdf;jsessionid=1BC306D15B49D1385E9F327EB3F8B81F.2_cid321?__blob=publicationFile&v=6

Bocoum, Ibrahima, Macombe Catherine and Reveret, Jean-Pierre. 2015. Anticipating impacts on health based on changes in income inequality caused by life cycles. The International Journal of Life Cycle Assessment, 20(3), 405–417. . [Retrieved March 16, 2021]. From: https://doi.org/10.1007/s11367-014-0835-x

Brazier, John and Tsuchiya, Aki. 2015. Improving Cross-Sector Comparisons: Going Beyond the Health-Related QALY. Applied health economics and health policy. [Online] 13 (6), 557–565. [Retrieved January 21, 2021]. From: https://doi.org/10.1007/s40258-015-0194-1

Cabinet du Président de la République. 2018. Code Minier de la RDC. [Retrieved July 8, 2021]. From: https://www.mines-rdc.cd/fr/wp-content/uploads/Code%20minier/J.O._n%C2%B0_spe%C3%ACcial_du_28_mars_2018_CODE_MINIER%20DE%20LA%20RDC.PDF

Chen, Zhenyang, Zhang, Lingen and Xu, Zhenming. 2019. Tracking and quantifying the cobalt flows in mainland China during 1994–2016: Insights into use, trade and prospective demand. The Science of the Total Environment, 672, 752–762. [Retrieved March 8, 2021]. From: https://doi.org/10.1016/j.scitotenv.2019.02.411

Cheyns, Karlien, Banza Lubaba Nkulu, Celestin, Ngombe, Leon Kabamba, Asosa, Jimmy Ngoi, Haufroid, Vincent, De Putter Thierry, Nawrot, Tim, Kimpanga, Celestin Muleka, Numbi, Oscar Luboya, llunga, Benjamin Kabyla, Nemery, Benoit and Smolders, Erik. 2014. Pathways of human exposure to cobalt in Katanga, a mining area of the D.R. Congo. The Science of the Total Environment, 490, 313–321. [Retrieved March 8, 2021]. From: https://doi.org/10.1016/j.scitotenv.2014.05.014

Chokunonga E., Borok MZ., Chirenje ZM., Nyabakau AM., Parkin DM. 2011. Cancer survival in Harare, Zimbabwe, 1993-1997. IARC Sci Publ. 2011;(162):249-55. [Retrieved July 26, 2021]. From: https://survcan.iarc.fr/survival/chap31.pdf

CleanTechnica. 2021. Tesla Transitions to Battery Cells for Megapack Installations. [Retrieved June 19, 2021]. From: https://cleantechnica.com/2021/05/11/tesla-transitions-to-lfp-battery-cells-for-megapack-installations/

Clark, David A. 2014. Defining and Measuring Human Well-Being. Global Environmental Change. [Online]. Dordrecht: Springer Netherlands. pp. 833–855. [Retrieved July 5, 2021]. From: https://doi.org/10.1007/978-94-007-5784-4_66

Cobalt Institute. 2021. Critical Raw Material. [Retrieved June 20, 2021]. From: https://www.cobaltinstitute.org/critical-raw-material.html

Cookson, Richard, Ieva Skarda, Owen Cotton-Barratt, Matthew Adler, Miqdad Asaria, and Toby Ord. 2021. Quality adjusted life years based on health and consumption: A summary wellbeing measure for cross-sectoral economic evaluation. Health economics. [Online] 30 (1), 70–85. [Retrieved June 1, 2021]. From: https://doi.org/10.1002/hec.4177

Cordaid. 2020. DEUX ANS APRES LA REVISION DU CODE MINIER EN REPUBLIQUE DEMOCRATIQUE DU CONGO: LES COMMUNAUTES LOCALES EN ATTENTE DES RETOMBEES SOCIETALES. [Retrieved March 18, 2021]. From: https://www.cordaid.org/en/news/evaluation-of-revised-mining-code-and-sustainable-development-in-dr-congo/

Cordaid. 2015. L'EXPLOITATION MINIERE AU CŒUR DES ZONES RURALES : QUEL DÉVELOPPEMENT POUR LES COMMUNAUTÉS LOCALES ?. [Retrieved March 8, 2021]. From: https://www.cordaid.org/media/medialibrary/2016/01/2015_Katanga_Baseline_Report_extractives.pdf

CRU. 2018. Artisanal mining will balance the cobalt market. [Retrieved March 8, 2021]. From: https://www.crugroup.com/knowledge-and-insights/insights/2018/artisanal-mining-will-balance-the-cobalt-market/

Crundwell, F.K, du Preez, N.B and Knights, B.D.H. 2020. Production of cobalt from copper-cobalt ores on the African Copperbelt – An overview. Minerals Engineering, 156, 106450–. [Retrieved March 16, 2021] From: https://doi.org/10.1016/j.mineng.2020.106450

Cuvelier, Jeroen. 2014. Work and masculinity in Katanga's artisanal mines/Arbeit und mannlichkeit im kleinbergbau Katangas. Afrikaspectrum. 49 (2), 3–. [Retrieved March 12, 2021]. From: https://doi-org.ezproxy.cc.lut.fi/10.1177/000203971404900201

Dai, Qian, Kelly, Jarod and Elgowainy, Amgad. 2018. Update of Life Cycle Analysis of Cobalt in the GREET model. [Retrieved March 18, 2021]. From: https://greet.es.anl.gov/publication-update_cobalt

Deng, Xinming, and Yang Xu. 2017. Consumers' Responses to Corporate Social Responsibility Initiatives: The Mediating Role of Consumer–Company Identification. Journal of business ethics. [Online] 142 (3), 515–526. [Retrieved July 5, 2021]. From: https://doi.org/10.1007/s10551-015-2742-x

Deng, Mingming, Feng Wu, Jun Wang, and Linyan Sun. 2017. Musculoskeletal disorders, personality traits, psychological distress, and accident proneness of Chinese coal miners. Work (Reading, Mass.). [Online] 57 (3), 441–449. [Retrieved June 30, 2021]. From: https://doi.org/10.3233/WOR-172569

Desai, Pratima and Nguen, Mai. 2021. Shortages flagged for EV materials lithium and cobalt. [Retrieved July 9, 2021]. From: https://www.reuters.com/business/energy/shortages-flagged-ev-materials-lithium-cobalt-2021-07-01/

Devleesschauwer, Brecht, Arie H Havelaar, Charline Maertens De Noordhout, Juanita A Haagsma, Nicolas Praet, Pierre Dorny, Luc Duchateau, Paul R Torgerson, Herman Van Oyen, and Niko Speybroeck. 2014. DALY calculation in practice : A stepwise approach. International journal of public health. [Online] 59 (3), 571–574. [Retrieved June 20, 2021]. From: https://doi.org/10.1007/s00038-014-0553-y

Du, Jiuyu, Minggao Ouyang, Xiaogang Wu, Xiangfeng Meng, Jianqiu Li, Feiqiang Li, and Ziyou Song. 2019. Technological direction prediction for battery electric bus under influence of China's new subsidy scheme. Journal of cleaner production. [Online] 222267–279. [Retrieved July 30, 2021]. From: https://doi.org/10.1016/j.jclepro.2019.02.249

Elenge, Myriam, Leveque, Alain and De Brouvier, Christophe. 2013. Occupational accidents in artisanal mining in Katanga, D.R.C. Occupational medicine and Environmental health vol. 26. [Retrieved March 12, 2021]. From: https://doi.org/10.2478/s13382-013-0096-0

Elenge, Myriam and De Brouvier, Christophe. 2010. Identification of hazards in the workplaces of artisanal mining in Katanga. Occupational medicine and Environmental health vol. 24. [Retrieved March 12, 2021]. From: https://doi.org/10.2478/s13382-011-0012-4

Elkington, John. 1998. Partnerships from cannibals with forks: The triple bottom line of 21st-century business. Environmental quality management. [Online] 8 (1), 37–51. [Retrieved June 2021]. From: https://doi.org/10.1002/tqem.3310080106

Ericsson, Magnus, Löf, Olof, Löf, Anton 2020. Chinese control over African and Global Mining – past, present, and future. Mineral Economics : Raw Materials Report, 33(1-2), 153–181. [Retrieved February 11, 2021]. From: https://doi.org/10.1007/s13563-020-00233-4

European Parliament. 2020. Social sustainability – Concepts and Benchmarks. [Retrieved June 1, 2021]. From: https://www.europarl.europa.eu/RegData/etudes/STUD/2020/648782/IPOL_STU(2020)648782_EN.pdf

Faber, Benjamin, Krause, Benjamin and Sánchez De La Sierra, Raúl. 2017. Artisanal Mining, Livelihoods, and Child Labor in the Cobalt Supply Chain of the Democratic Republic of Congo. Center for Effective Global Action Policy Report. [Retrieved August 1, 2021]. From: http://cega.berkeley.edu/assets/cega_research_projects/179/CEGA_Report_v2.pdf

Fairphone. 2020. How much does a miner earn? Assessment of Miner's revenue & Basic Needs study in the DRC. [Retrieved July 26, 2021]. From: https://www.fairphone.com/wp-content/uploads/2020/05/Fairphone-report_final.pdf

Fair Wage database. 2016. Fair wage equivalents. [Retrieved March 19, 2021]. From: https://www.see.tu-berlin.de/menue/research/data_tools/fair_wage_equivalents/parameter/en/

Feschet, Pauline, Macombe, Catherine, Garrabe, Michel, Loeillet, Denis, Saez, Adolfo Rolo and Benhmad, Francois. 2013. Social impact assessment in LCA using the Preston pathway: The case of banana industry in Cameroon. The International Journal of Life Cycle Assessment, 18(2), 490–503. [Retrieved March 16, 2021]. From: https://doi.org/10.1007/s11367-012-0490-z

Frankel, Todd. 2016. The Cobalt Pipeline. [Retrieved February 2, 2021]. From: https://www.washingtonpost.com/graphics/business/batteries/congo-cobalt-mining-for-lithium-ion-battery/

Furberg, Anna, Arvidsson, Rickard and Sverker, Molander. 2018. Live and Let Die? Life Cycle Human Health Impacts from the Use of Tire Studs. International Journal of Environmental Research and Public Health, 15(8), 1774–. [Retrieved March 16, 2021]. From: https://doi.org/10.3390/ijerph15081774

GBD. 2019. Disability weights. [Retrieved March 16, 2021]. From: http://ghdx.healthdata.org/gbd-results-tool

Geenen, Sara, Nik Stoop, and Marijke Verpoorten. 2021. How much do artisanal miners earn? An inquiry among Congolese gold miners. Resources policy. [Online]. 70101893–. [Retrieved June 1, 2021]. From: https://doi.org/10.1016/j.resourpol.2020.101893

GSIF. 2018. Weaving the Web. Documenting the Good Shepherd Sister's Approach to Community-Based Development and Child Protection in Kolwezi, Democratic Republic of Congo. [Retrieved July 29, 2021]. From: http://www.fondazionebuonpastore.org/resources/GSIF-CPC_report_WeavingtheWeb_Congo_1.4.pdf

GRI. 2020. GRI standards. [Retrieved June 1, 2021]. From: https://www.globalreporting.org/standards/download-the-standards/

GSS. 2013. GSS Research – violence and abuse against women, girls and children in artisinal mining communities of the DRC. Democratic Republic Congo: Good Sheperd Sisters. [Retrieved August 6, 2021].

Gulley, Andrew, McCullough, Erin and Shedd, Kim. 2019. China’s domestic and foreign influence in the global cobalt supply chain. [Retrieved February 21, 2021]. From: https://doi.org/10.1016/j.resourpol.2019.03.015

Gyamfi, Charles Kwame R, Isaac Amankwaa, Frank Owusu Sekyere, and Daniel Boateng. 2016. Noise Exposure and Hearing Capabilities of Quarry Workers in Ghana: A Cross-Sectional Study. Journal of environmental and public health. [Online] 20167054276–7054277. [Retrieved June 19, 2021]. From: https://doi.org/10.1155/2016/7054276

Hayes, Karen and Perks, Rachel. 2012. Women in the artisanal and small-scale mining sector of the Democratic Republic of the Congo. ed. P. Lujala and S. A. Rustad. London: Earthscan. [Retrieved June 1, 2021]. From: https://elr.info/sites/default/files/529-544_hayes_and_perks.pdf

He, Zekai, Shi, Xiuzhen, Wang, Xinhao and Xu, Yuwei. 2017. Urbanisation and the geographic concentration of industrial SO2 emissions in China. Urban Studies (Edinburgh, Scotland), 54(15), 3579–3596. [Retrieved March 16, 2021]. From: https://doi.org/10.1177/0042098016669915

Helmers, Eckard, Johannes Dietz, and Martin Weiss. 2020. Sensitivity Analysis in the Life-Cycle Assessment of Electric vs. Combustion Engine Cars under Approximate Real-World Conditions. Sustainability (Basel, Switzerland). [Online] 12 (3), 1241–. [Retrieved 30, 2021]. From: https://doi.org/10.3390/su12031241

Hosseinijou, Seyes Abbas, Mansour, Saeed and Shirazi, Mohsen Akbarpour. 2014. Social life cycle assessment for material selection: a case study of building materials. The International Journal of Life Cycle Assessment, 19(3), 620–645. [Retrieved March 16, 2021]. From: https://doi.org/10.1007/s11367-013-0658-1

Härri, Anna. 2019. Transcriptions of interviews conducted in DRC. Pro ethical trade Finland. Unpublished.

International Council of Mining and Metals. 2021. Occupational diseases. [Retrieved August 5, 2021]. From: https://www.icmm.com/en-gb/health-and-safety/health/occupational-health

ILO. 2021a. The Worst forms of Child labour. [Retrieved February 21, 2021]. From: https://www.ilo.org/ipec/Campaignandadvocacy/Youthinaction/C182-Youth-orientated/worstforms/lang--en/index.htm

ILO. 2021b. International Labour Standards on Working time. [Retrieved May 6, 2021]. From: https://www.ilo.org/global/standards/subjects-covered-by-international-labour-standards/working-time/lang--en/index.htm

ILO. 2011. Children in hazardous work. What we know. What we need to know. [Retrieved July 26, 2021]. From: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_155428.pdf

Industriall. 2020. Workers paid allowance after strike at DRC mine. [Retrieved June 19, 2021]. From: http://www.industriall-union.org/workers-paid-allowance-after-strike-at-drc-mine

Industriall. 2018a. DRC: Industriall supports new mining code, demands greater share for workers. [Retrieved June 1, 2021]. From: http://www.industriall-union.org/drc-industriall-supports-mining-code-demands-greater-share-for-workers

Industriall. 2018b. Profile: TUMEC – Organizing and defending Congolese workers' rights. [Retrieved June 1, 2021]. From: http://www.industriall-union.org/profile-tumec-organizing-and-defending-congolese-workers-rights

Industriall. 2016. Workers killed at Glencore's Katanga mine in Congo. [Retrieved June 1, 2021]. From: http://www.industriall-union.org/workers-killed-at-glencores-katanga-mine-in-congo-0

International Energy Agency. 2020. Global EV Outlook 2020. [Retrieved January 21, 2021]. From: https://www.iea.org/reports/global-ev-outlook-2020

IPCC. 2018. Global warming of 1,5 C. [Retrieved January 21, 2021]. From: https://www.ipcc.ch/sr15/

Jeripotula, Sandeep Kumar, Aruna Mangalpady, and Govinda Raj Mandela. 2020. (2020) Musculoskeletal Disorders Among Dozer Operators Exposed to Whole-Body Vibration in Indian Surface Coal Mines. Mining, metallurgy & exploration. [Online] 37 (2), 803–811. [Retrieved June 1, 2021]. From: https://doi.org/10.1007/s42461-019-00170-z

Katz-Lavigne, Sarah. 2020. Distributional impact of corporate extraction and (un)authorised clandestine mining at and around large-scale copper- and cobalt-mining sites in DR Congo. Resources Policy, 65, 101584–. [Retrieved March 10, 2021]. From: https://doi.org/10.1016/j.resourpol.2020.101584

Katz-Lavigne, Sarah. 2019. Artisanal copper mining and conflict at the intersection of property rights and corporate strategies in the Democratic Republic of Congo. The extractive industries and society. [Online] 6 (2), 399–406. [Retrieved July 26, 2021]. From: https://doi.org/10.1016/j.exis.2018.12.001

Kallitsis, E., Korre, A., Kelsall, G., Kupfersberger, M., & Nie, Z. (2020). Environmental life cycle assessment of the production in China of lithium-ion batteries with nickel-cobalt-manganese cathodes utilising novel electrode chemistries. Journal of Cleaner Production, 254, 120067–. https://doi.org/10.1016/j.jclepro.2020.120067

Kannah, Junior. 2019. 10 000 families to be moved from DR Congo cobalt site – provincial governor. [Retrieved June 1, 2021]. From:

https://www.news24.com/news24/Africa/News/10-000-families-to-be-moved-from-dr-congo-cobalt-site-provincial-governor-20191218

Kara, Siddharth. 2018. Is your phone tainted by the misery of the 35,000 children in Congo's mines?. The Guardian. [Retrieved March 10, 2021]. From: https://www.theguardian.com/global-development/2018/oct/12/phone-misery-children-congo-cobalt-mines-drc

King, Matthew, Davenport, William George and Moats, Michael. 2013. Sulfuric acid manufacture analysis, control and optimization. 2nd ed. Elsevier.

Kühnen, Michael and Hahn, Rüdiger. 2017. Indicators in Social Life Cycle Assessment. Journal of Industrial Ecology. [Retrieved January 21, 2021]. From: https://doi.org/10.1111/jiec.12663

Kyeremateng-Amoah, E., Clarke, Edisth E. 2015. njuries among Artisanal and Small-Scale Gold Miners in Ghana. International journal of environmental research and public health. [Online] 12 (9), 10886–10896. [Retrieved August 3, 2021]. From: https://doi.org/10.3390/ijerph120910886

Le Bec, Christophe and Banda, Honoré. DRC: COVID-19 and cobalt crash make a one-two punch. [Retrieved May 5, 2021]. From: https://www.theafricareport.com/45389/drc-covid-19-and-cobalt-crash-make-a-one-two-punch/

Leung, Chi Chiu, Ignatius Tak Sun Yu, and Weihong Chen. 2012. Silicosis. The Lancet (British edition). [Online] 379 (9830), 2008–2018. [Retrieved June 19, 2021]. From: https://doi.org/10.1016/S0140-6736(12)60235-9

Life Cycle Initiative. 2020. Guidelines for Social Life Cycle Assessment of Products and Organizations 2020. [Retrieved January 21, 2021]. From: https://www.lifecycleinitiative.org/library/guidelines-for-social-life-cycle-assessment-of-products-and-organisations-2020/

Mancini, Lucia, Nicolas A Eslava, Marzia Traverso, and Fabrice Mathieux. 2021. Assessing impacts of responsible sourcing initiatives for cobalt: Insights from a case study. Resources policy. [Online] 71102015–. [Retrieved July 29, 2021]. From: https://doi.org/10.1016/j.resourpol.2021.102015

Majeau-Bettez, Guillaume, Hawkings, Troy R. and Strømman, Hammer. 2011. Life Cycle Environmental Assessment of Lithium-Ion and Nickel Metal Hydride Batteries for Plug-in Hybrid and Battery Electric Vehicles. Supporting Information. [Retrieved March 17, 2021]. From: https://doi.org/10.1021/es2015082

Manthiram, Arumugang. 2020. A reflection on lithium-ion battery cathode chemistry. Nature Communications 11. Nature. [Retrieved March 8, 2021]. From: https://www.nature.com/articles/s41467-020-15355-0

Mayaux, Philippe. 2012. The Congo Basin vegetation types map. [Retrieved March 19, 2021]. From: https://www.researchgate.net/figure/The-Congo-Basin-vegetation-types-map_fig3_245032317

McDonald, Scott, Juanita Haagsma, Alessano Cassini, and Brecht Devleesschauwer. 2020. Adjusting for comorbidity in incidence-based DALY calculations: an individual-based modeling approach. BMC medical research methodology. [Online] 20 (1), 100–100. [Retrieved June 22, 2021]. From: https://doi.org/10.1186/s12874-020-00987-z

McKinsey & Company. 2018. Lithium and cobalt – a tale of two commodities. Metals and Mining. [Retrieved March 8, 2021]. From: https://www.mckinsey.com/industries/metals-and-mining/our-insights/lithium-and-cobalt-a-tale-of-two-commodities

McCormack, Valerie A, and Joachim Schüz. 2011. Africa's growing cancer burden: Environmental and occupational contributions. Cancer epidemiology. [Online] 36 (1), 1–7. [Retrieved June 19, 2021]. From: https://doi.org/10.1016/j.canep.2011.09.005

Mielke, Stefan, Dirk Taeger, Kerstin Weitmann, Thomas Brüning, and Wolfgang Hoffmann. 2018. Influence of quartz exposure on lung cancer types in cases of lymph node-only silicosis and lung silicosis in German uranium miners. Archives of environmental & occupational health. [Online] 73 (3), 140–153. [Retrieved 1 June, 2021]. From: https://doi.org/10.1080/19338244.2017.1322933

Mihaljevič, Martin, Ettler, Vojtech, Šebek, Ondrej, Sracek, Ondra, Kříbek, Bohdan, Kyncl, Tomas, Majer, Vladimir and Veselovský, Frantisek. 2011. Lead Isotopic and Metallic Pollution Record in Tree Rings from the Copperbelt Mining–Smelting Area, Zambia. Water, Air, & Soil Pollution, 216(1), 657–668. [Retrieved March 8, 2021]. From: https://doi.org/10.1007/s11270-010-0560-4

MPSMRM. 2014. Democratic Republic of Congo Demographic and Health Survey 2013-14: Key Findings. [Retrieved July 30, 2021]. From: https://dhsprogram.com/publications/publication-fr300-dhs-final-reports.cfm

Morris, James. 2020. Teslas's Shift to Cobalt-Free Batteries Is Its Most Important Move Yet. Forbes. [Retrieved July 30, 2021]. From: https://www.forbes.com/sites/jamesmorris/2020/07/11/teslas-shift-to-cobalt-free-batteries-is-its-most-important-move-yet/?sh=1b1f996646b4

Niarchos, Nicolas. 2021. The Dark Side of Congo's Cobalt Rush. The New Yorker. [July 12, 2021]. From: https://www.newyorker.com/magazine/2021/05/31/the-dark-side-of-congos-cobalt-rush

NS Energy Group. 2021. Profiling the world's top five copper mining countries in 2020. [Retrieved July 29, 2021]. From: https://www.nsenergybusiness.com/news/top-five-copper-mining-countries

National institutes of Health. 2020. The Stages of HIV Infection. [Retrieved June 19, 2021]. From: https://hivinfo.nih.gov/understanding-hiv/fact-sheets/stages-hiv-infection

Nikkei Asia. 2021. Cheaper Tesla. Panasonic to develop cobalt-free battery. [Retrieved June 20, 2021]. From: https://asia.nikkei.com/Business/CES-2021/Cheaper-Tesla-Panasonic-to-develop-cobalt-free-battery

Office of Retirement and Disability Policy. 2019. Social Security Programs Throughout the World: Africa, 2019. [Retrieved June 1, 2021]. From: https://www.ssa.gov/policy/docs/progdesc/ssptw/2018-2019/africa/congo-democratic-republic-of-the.html

Onder, Seyhan. 2013. Evaluation of occupational injuries with lost days among opencast coal mine workers through logistic regression models. Safety science. [Online] 5986–92. [Referred June 19, 2021]. From: https://doi.org/10.1016/j.ssci.2013.05.002

Park, Bohying, Park, Bomi, Lee Won Kying, Kim Young-Eun, Yoon, Seok-Jun and Park, Hyesook. 2019. Incidence-Based versus Prevalence-Based Approaches on Measuring Disability-Adjusted Life Years for Injury. Journal of Korean Medical Science. [Retrieved July 29, 2021]. From: https://doi.org/10.3346/jkms.2019.34.e69

Passer, Alexander, Lasvaux, Sebastien, Allacker, Karen, De Lathauwer, Dieter, Spirinckx, Carolin, Wittstock, Bastian, Kellenberger, Daniel, Gschösser. Florian, Wall, Johannes and Wallbaum. Holger. Environmental product declarations entering the building sector: critical reflections based on 5 to 10 years experience in different European countries. Int J Life Cycle Assess 20, 1199–1212 (2015). [Retrieved March 8, 2021]. From: https://doi.org/10.1007/s11367-015-0926-3

Perks, Rachel. 2011. 'Can I go?' -Exiting the artisanal mining sector in the Democratic Republic of Congo. Journal of International Development, 23(8), 1115–1127. [Retrieved March 12, 2021]. From: https://doi.org/10.1002/jid.1835

Pradhan, Prajal, Costa, Luis, Rybski, Diego, Lucht, Wolfgang and Kropp, Jürgen. 2017. A systematic study of Sustainable Development Goal (SDG) interactions. Earth's Future.

5(11): pp.1169–1179. [Retrieved January 22, 2021]. From: https://doi.org/10.1002/2017EF000632

RAID. 2021. DR Congo Stands to Lose $3.71 billion in Mining Deals with Dan Gertler. [Retrieved June 1, 2021]. From: https://www.raid-uk.org/blog/drc-congo-stands-lose-3-71-billion-mining-deals-dan-gertler

RAID. 2019. Democratic Republic of Congo: congo's victims of corruption. [Retrieved March 12, 2021]. From: https://www.raid-uk.org/victimsofcorruption

RAID. 2009. Chinese mining operations in Katanga Democratic Republic of the Kongo. [Retrieved June 1, 2021]. From: https://www.raid-uk.org/sites/default/files/drc-china-report.pdf

Reuters. 2020. Congo grants new export ban waivers for copper, cobalt, tin. [Retrieved February 10, 2021]. From: https://www.reuters.com/article/us-congo-mining-idUSKBN25I0LR

Rockström, J., Steffen, W., Noone, K. et al. 2009. A safe operating space for humanity. Nature **461,** 472–475. [Retrieved June 20, 2021]. From: https://doi.org/10.1038/461472a

Santoro, Licia, Tshipeng, Steev, Pirard, Eric, Bouzahzah, Hassan. Kaniki, Arthur and Herrington, Richard. 2019. Mineralogical reconciliation of cobalt recovery from the acid leaching of oxide ores from five deposits in Katanga (DRC). Minerals engineering. [Online] 137277–289. [Retrieved March 8, 2021]. From: https://doi.org/10.1016/j.mineng.2019.02.011

Saunders, J.E., Jastrzembski, B.G., Buckey, J.C., Enriquez, D., MacKenzie, T.A., Karagas, M.R. 2013. Hearing loss and heavy metal toxicity in a Nicaraguan mining community: Audiological results and case reports. Audiol. Neurotol. 18, 101–113. [Retrieved August 6, 2021]. From: https://doi.org/10.1159/000345470

Schaubroeck, Thomas and Rugani, Benedetto. 2017. Schaubroeck, T., & Rugani, B. 2017. A Revision of What Life Cycle Sustainability Assessment Should Entail: Towards Modeling the Net Impact on Human Well-Being. Journal of Industrial Ecology, 21(6), 1464–1477. [Retrieved March 16, 2021]. From: https://doi.org/10.1111/jiec.12653

Schmitz, Allison. 2016. Benzodiazepine use, misuse, and abuse: A review. Mental Health Clinician (2016) 6 (3): 120–126. [Retrieved July 30, 2021]. From: https://doi.org/10.9740/mhc.2016.05.120

Schwartz, Franklin W, Sangsuk Lee, and Thomas H Darrah. 2021. A Review of Health Issues Related to Child Labor and Violence Within Artisanal and Small-Scale Mining. GeoHealth. [Online] 5 (2),. [Retrieved June 19, 2021]. From: https://doi.org/10.1029/2020GH000326

SFS-EN ISO 14040:2006/A1:2020:en. 2020. Environmental management. Life cycle assessment. Principles and framework. [e-document]. [Retrieved March 16, 2021]. From: https://online-sfs-fi.ezproxy.cc.lut.fi/fi/index/tuotteet/SFS/CENISO/ID2/1/935595.html.stx

SFS-EN ISO 14044:2006/A2:2020:en. 2020. Environmental management. Life cycle assessment. Requirements and guidelines. [e-document]. [Retrieved March 16, 2021]. From: https://online-sfs-fi.ezproxy.cc.lut.fi/fi/index/tuotteet/SFS/CENISO/ID2/1/935586.html.stx

Shamraiz, Ahmad, Yew Wong, Kuan and Rajoo, Srithar. 2019. Sustainability indicators for manufacturing sectors: A literature survey and maturity analysis from the triple-bottom line perspective. Journal of manufacturing technology management. [Online] 30 (2), 312–334. [Retrieved June 20, 2021]. From: https://doi.org/10.1108/JMTM-03-2018-0091

Shutcha, Mylor Ngoy, Faucon, Michel-Pierre, Kamengwa Kissi, Ckeface, Colinet, Gilles, Mahy, Gregory, Ngongo Luhembwe, Michael, Visser, Marjolein, and Meerts, Pierre. 2015. Three years of phytostabilisation experiment of bare acidic soil extremely contaminated by copper smelting using plant biodiversity of metal-rich soils in tropical Africa (Katanga, DR

Congo). Ecological Engineering, 82, 81–90. [Retrieved March 16, 2021]. From: https://doi.org/10.1016/j.ecoleng.2015.04.062

Smolders, Erik, Roles, Lore, Kuhangana, Tresor Carsi, Coorevits, Kristin, Vassilieva, Elvira, Nemery, Benoit and Banza Lubaba Nkulu, Celestin. 2019. Unprecedentedly High Dust Ingestion Estimates for the General Population in a Mining District of DR Congo. Environmental Science & Technology, 53(13), 7851–7858. [Retrieved March 8, 2021]. From: https://doi.org/10.1021/acs.est.9b01973

Sovacool, Benjamin. 2021. When subterranean slavery supports sustainability transitions? power, patriarchy, and child labor in artisanal Congolese cobalt mining. The Extractive Industries and Society, 8(1), 271–293. [Retrieved March 10, 2021]. From: https://doi.org/10.1016/j.exis.2020.11.018

Sovacool, Benjamin. 2019. The precarious political economy of cobalt: Balancing prosperity, poverty, and brutality in artisanal and industrial mining in the Democratic Republic of the Congo. [Retrieved February 16, 2020]. From: https://doi.org/10.1016/j.exis.2019.05.018

Statista. 2021. Global plug-in electric vehicle market share in 2020, by main producer. [Retrieved July 30, 2021]. From: https://www.statista.com/statistics/541390/global-sales-of-plug-in-electric-vehicle-manufacturers/

Stein, Alexander and Qaim, Martin. 2007. The Human and Economic Cost of Hidden Hunger. Food and Nutrition Bulletin, 28(2), 125–134. [Retrieved March 8, 2021]. From: https://doi.org/10.1177/156482650702800201

Stemn, Eric. 2019. Analysis of Injuries in the Ghanaian Mining Industry and Priority Areas for Research. [Retrieved June 19, 2021]. From: https://doi.org/10.1016/j.shaw.2018.09.001

Stockholm Resilience Center. 2021. The nine planetary boundaries. [Retrieved June 1, 2021]. From: https://www.stockholmresilience.org/research/planetary-boundaries/the-nine-planetary-boundaries.html

Sun, Peiyi, Roeland Bisschop, Huichang Niu, and Xinyan Huang. 2020. A Review of Battery Fires in Electric Vehicles. [Retrieved July 30, 2021]. From: https://doi.org/10.1007/s10694-019-00944-3

Sustainable Bus. 2019. LFP in China, NMC in Western countries. Electric bus market split between two battery technologies. [Retrieved June 19, 2019]. From: https://www.sustainable-bus.com/news/lfp-battery-industry-is-driven-by-chinese-electric-bus-market-reasons-for-a-dominance-bus/

Tae-Woo Kim, Dong-Hee Koh and Chung-Yill Park. 2010. Decision Tree of Occupational Lung Cancer Using Classification and Regression Analysis. Safety and Health at Work, Volume 1, Issue 2, Pages 140-148. [Retrieved July 26, 2021]. From: https://doi.org/10.5491/SHAW.2010.1.2.140

Thies, Christian, Kieckhäfer, Karsten, Spengler, Thomas S. and Sodhi, Manbir S. 2019. Assessment of social sustainability hotspots in the supply chain of lithium-ion batteries. [Retrieved June 20, 2021]. From: https://doi.org/10.1016/j.procir.2018.12.009

TTK. 2015. Kaivosturvallisuusopas. [Retrieved June 19, 2021]. From: https://ttk.fi/files/6409/Kaivosturvallisuusopas.pdf

TTL. 2021. Kemikaalit ja työ. [Retrieved April 8, 2021]. From: https://www.ttl.fi/kemikaalit-ja-tyo/

Tull, Kerina. 2018. Social protection measures for increasing access to health services. [Retrieved June 1, 2021]. From: https://assets.publishing.service.gov.uk/media/5c6c2d5be5274a72b74654f9/health.pdf

Tshipeng, Steev Yav, Tshamala Kaniki, Arthur and Kime, Meschac-Bill. 2017. Effects of the Addition Points of Reducing Agents on the Extraction of Copper and Cobalt from Oxidized Copper–Cobalt Ores. Journal of Sustainable Metallurgy, 3(4), 823–828. [Retrieved March 10, 2021]. From: https://doi.org/10.1007/s40831-017-0149-x

Turcheniuk, Konstantyn, Bondarev, Dmitry, Singhal, Vinod and Yushin, Gleb. 2018. Ten years left to redesign lithium-ion batteries. [Retrieved January 22, 2021]. From: https://www.nature.com/articles/d41586-018-05752-3

UNAIDS. 2021. Map. [Retrieved June 19, 2021]. From: https://aidsinfo.unaids.org/

Unicef. 2019. REPUBLIQUE DEMOCRATIQUE DU CONGO MICS-Palu 2018. Rapport Final. [Retrieved April 27, 2021]. From: https://mics.unicef.org/surveys

United Nations. 2020. Social sustainability. [Retrieved June 1, 2021]. From: https://www.unglobalcompact.org/what-is-gc/our-work/social

United Nations. 2019a. GLOBAL CONFERENCE ON STRENGTHENING SYNERGIES BETWEEN THE PARIS AGREEMENT ON CLIMATE CHANGE AND THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT. Conference summary. [Retrieved June 20, 2021]. From: https://sustainabledevelopment.un.org/climate-sdgs-synergies2019

United Nations. 2019. World Population Prospects 2019. [Retrieved June 20, 2021]. From: https://population.un.org/wpp/

United Nations. 2015. Transforming out world: The 2030 Agenda for Sustainable Development. [Retrieved January 22, 2021]. From: https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981

US5753200A. 1998. Sodium metabisulfite process. Google Patents. [Retrieved March 17, 2021]. From: https://patents.google.com/patent/US5753200A/en

USGS. 2021. Mineral commodity summary: Cobalt. [Retrieved March 10, 2021]. From: https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-cobalt.pdf

Vaan Brusselen, Daan, Kayambe-Kitenge, Tony, Mbuyi-Musanzayi, Sébastien and Lubala Kasole, Toni. 2020. Metal mining and birth defects: a case-control study in Lubumbashi, Democratic Republic of the Congo. Lancet Planet Health. [Retrieved March 10, 2021]. From: https://doi.org/10.1016/S2542-5196(20)30059-0

Wabinga H., Parkin DM., Nambooze S. and Amero J. 2011. Cancer survival in Kampala, Uganda, 1993-1997. IARC Sci Publ. 2011;(162):243-7. [Retrieved July 26, 2021]. From: https://survcan.iarc.fr/survival/chap30.pdf

Vallance, Suzanne, Harvey C Perkins, and Jennifer E Dixon. 2011. What is social sustainability? A clarification of concepts. Geoforum, 42(3), 342–348. [Retrieved August 1, 2021]. From: https://doi.org/10.1016/j.geoforum.2011.01.002

Van den Brink, Susan, Kleijn, René, Sprecher, Benjamin and Tukker, Arnold. 2020. Identifying supply risks by mapping the cobalt supply chain. Resources, Conservation and Recycling. [Retrieved March 10, 2021]. From: https://doi.org/10.1016/j.resconrec.2020.104743

Weidema, Bo. 2019. Towards a Taxonomy for Social Impact Pathway Indicators. Towards a Taxonomy for Social Impact Pathway Indicators. In Perspectives on Social LCA (pp. 11–23). Springer International Publishing. [Retrieved March 10, 2021]. From: https://doi.org/10.1007/978-3-030-01508-4_2

Weidema, Bo. 2006. The Integration of Economic and Social Aspects in Life Cycle Impact Assessment. The International Journal of Life Cycle Assessment, 11(S1), 89–96. [Retrieved March 10, 2021]. From: https://doi.org/10.1065/lca2006.04.016

WHO. 2021a. Malaria. [Retrieved June 19, 2021]. From: https://www.who.int/news-room/fact-sheets/detail/malaria

WHO. 2020a. Newborns: improving survival and well-being. [Retrieved June 19, 2021]. From: https://www.who.int/news-room/fact-sheets/detail/newborns-reducing-mortality

WHO. 2020b. The top 10 causes of death. [Retrieved July 30, 2021]. From: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death

WHO. 2018. WHO methods and data sources for global burden of disease estimates 2000-2016. [Retrieved July 31, 2021]. From: https://www.who.int/healthinfo/global_burden_disease/GlobalDALY_method_2000_2016.pdf

WHO. 2003. Assessing the environmental burden of disease at national and local levels. [Retrieved June 22, 2021]. From: https://www.who.int/quantifying_ehimpacts/publications/en/9241546204.pdf

World Bank. 2019a. Life expectancy at birth, total (years) – Congo, Dem. Rep. [Retrieved July 2021]. From: https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=CD

World Bank. 2019b. Life expectancy at birth, total (years) – Hong Kong SAR, China [Retrieved July 2021]. From: https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=HK

World Food Programme. 2020. Minimum Expenditure Basket (MEB) analysis – Democratic Republic of Congo-. [Retrieved June 20, 2021]. From: https://docs.wfp.org/api/documents/WFP-0000120023/download/

World Vision. 2013. Child Miners Speak: Key Findings on Children and artisanal Mining in Kambove DRC. [Retrieved June 19, 2021]. From:

https://www.wvi.org/sites/default/files/Child%20Miners%20Speak_WEB%20Version_0.pdf

Wu, Yu, Li, Rui, Cui, Lulu, Meng, Ya, Cheng, Hanyun and Fu, Hongbo. 2020. The high-resolution estimation of sulfur dioxide (SO2) concentration, health effect and monetary costs in Beijing. Chemosphere (Oxford), 241, 125031–125031. [Retrieved March 18, 2021]. From: https://doi.org/10.1016/j.chemosphere.2019.125031

Xie, Wushuang, Peng, Chi, Wang, Hongtao, and Chen, Weiping. 2017. Health Risk Assessment of Trace Metals in Various Environmental Media, Crops and Human Hair from a Mining Affected Area. International Journal of Environmental Research and Public Health, 14(12), 1595–. [Retrieved March 10, 2021]. From: https://doi.org/10.3390/ijerph14121595

Zvarivadza, Tawanda. 2018. Artisanal and Small-Scale Mining as a challenge and possible contributor to Sustainable Development. Resources Policy, 56, 49–58. [Retrieved March 10, 2021]. From: https://doi.org/10.1016/j.resourpol.2018.01.009

APPENDICES

List of respondents

Interviews by Pro Ethical Trade Finland 2019	
Respondent	Description
1	Local resident
2	NGO presentative
3	Premicongo NGO representative
4	Afrewatch representative
5	Director of the Provincial Ministry of Mines, Lualaba
6	Premicongo NGO representative
7	ASM miner
8	Local community representative
9	Local resident
10	Local resident

Inventory results per sub-process

ASM inventory													
Flow	DRC: Child labor	DRC: Excessive work ASM	DRC: Inadequate access to healthcare	DRC: Inadequate access to pensions or social security	DRC: Interpersonal or communal violence ASM	DRC: Labor union restriction	DRC: Occupational accidents ASM	DRC: Occupational diseases ASM	DRC: Occupational diseases children	DRC: Stressful working conditions ASM	DRC: Threats of violence or other contact crimes ASM	DRC: YLL due Occupational diseases and accidents ASM	DRC: YLL due Occupational diseases and accidents ASM Child
Alcohol problem use								8,60E-04					
Child labor	3,64E-05												
Excessive work		1,89E-03											
Fracture of patella, tibia or fibula, or ankle: short term,with or without treatment							1,53E-05						
Fracture of radius or ulna: short term, with or without treatment							2,82E-05						
Headache: tension-type								1,67E-03					
Hearing loss: mild								4,96E-04					
Inadequate access to health care			1,89E-03										
Inadequate access to pensions or social security				1,89E-03									
Injury to eyes: short term							4,72E-04		2,51E-05				
Interpersonal or communal violence					3,21E-05								
Labor union restrictions						1,89E-03							
Low back pain, moderate								1,72E-03					
Lung cancer metastatic								1,19E-06	1,90E-07				
Mild silicosis								8,58E-05	1,37E-05				
Moderate hearing loss								1,19E-04					
Moderate silicosis								2,42E-05	4,74E-06				
Mortality												7,89E-06	
Muscoskeletal problems upper limb pain moderate								3,10E-04					
Open wound: short term, with or without treatment							3,58E-04						
Other drug use disorders								1,45E-03					
Other musculoskeletal disorders severity level 1 (Leg pain)								4,32E-04	2,57E-04				
Poisoning: short term, with or without treatment									8,87E-05				
Severe hearing loss								4,63E-05					
Severe silicosis without heart failure									8,69E-07				
Skin irritation								6,08E-05	1,00E-04				
Stressful working conditions										1,89E-03			
Threats of violence or other contact crimes											1,89E-03		
YLL Lung cancer												2,52E-05	5,29E-06

LSM inventory					
Flow	DRC: Excessive work	DRC: Occupational accidents LSM	DRC: Occupational diseases LSM	DRC: Stressful working conditions	DRC: YLL due Occupational diseases and accidents LSM
Amputation of finger, thumb or toe		1,52325E-07			
Burns of <20% total surface area without lower airway burns: short term, with or without treatment		2,1543E-07			
Excessive work	0,000105519				
Foot pain moderate			1,2557E-05		
General fracture		3,9822E-07			
Hearing loss: mild			3,4821E-05		
Hip pain moderate			1,5068E-05		
Knee pain moderate			4,5215E-05		
Low back pain, moderate			8,7929E-05		
Lung cancer metastatic			7,7224E-08		
Mild silicosis			5,5601E-06		
Moderate hearing loss			8,3571E-06		
Moderate silicosis			1,5651E-06		
Mortality					1,45372E-08
Muscoskeletal problems upper limb pain moderate			9,0377E-05		
Neck pain moderate			5,0238E-05		
Open wound: short term, with or without treatment		6,44115E-07			
Other injuries of muscle and tendon		2,00198E-07			
Severe hearing loss			3,25E-06		
Stressful working conditions				0,00010552	
YLL Lung cancer					1,63468E-06

Local community inventory												
	DRC: Children out of school	DRC: Crime victim compensati on	DRC: Fair wage	DRC: Gender related restrictions	DRC: Interperson al or communal violence	DRC: Local community diseases ASM related	DRC: Local community diseases LSM related	DRC: Local employmen t	DRC: Refugees or internally displaced	DRC: Threats of violence or other contact crimes	DRC: Unequal opportuniti es	YLL Local community diseases
Flow												
AIDS with mild anemia						2,30E-05						
ASM pit manager			1,41E-04									
ASM worker			1,42E-03									
Children out of school	2,25E-03											
Crime victim compensation		1,07E-04										
Gender related participation restrictions				4,27E-03								
HIV/AIDS cases, receiving ARV treatment						9,11E-04						
Inadequate access to health care								2,09E-04				
Inadequate access to pensions or social security								2,09E-04				
Interpersonal or communal violence					7,36E-04							
LSM pit manager			1,92E-05									
LSM worker			1,94E-04									
Lung cancer metastatic							2,39E-07					
Mild silicosis							1,38E-06					
Moderate malaria						1,60E-03						
Refugees or internally displaced									1,07E-04			
Severe motor plus cognitive impairment with blindness						1,05E-06						
Symptomatic HIV with mild anemia						4,28E-04						
Threats of violence or other contact crimes										1,19E-03		
Yll Birth defects												3,59E-05
YLL HIV												2,04E-04
YLL Malaria												7,02E-04

Process inventory reference list

References by process			
Flow	DRC: Cobalt mining ASM	DRC: Cobalt mining community	DRC: Cobalt mining LSM
AIDS with mild anemia		GSS 2013 according to Schwartz et al. 2021; UNAIDS 2021;National institutes of Health 2020	
Alcohol problem use	Elenge et al. 2013		
Amputation of finger, thumb or toe			Stemn 2019
ASM pit manager		MPSMRM 2014; World Food Programme 2020; Geenen et al. 2021	
ASM worker		MPSMRM 2014; World Food Programme 2020; Geenen et al. 2021	
Burns of <20% total surface area without lower airway burns: short term, with or without treatment			Stemn 2019
Child labor	Kara 2018		
Children out of school		UNICEF 2019; United Nations 2019	
Crime victim compensation		Kannah 2019; Amnesty International 2019	
Excessive work	Amnesty International 2016; ILO 2021b		Respondent 4; Sovacool 2019; TTK 2015
Foot pain moderate			Jeripotula et al. 2020
Fracture of patella, tibia or fibula, or ankle: short term,with or without treatment	Elenge et al. 2013		
Fracture of radius or ulna: short term, with or without treatment	Elenge et al. 2013		

Gender related participation restrictions		United Nations 2019	
General fracture			Stemn 2019
Headache: tension-type	Elenge & De Brouver 2010		
Hearing loss: mild	Gyamfi et al. 2016; Basu et al. 2015		Gyamfi et al. 2016
Hip pain moderate			Jeripotula et al. 2020
HIV/AIDS cases, receiving ARV treatment		GSS 2013 according to Schwartz et al. 2021; UNAIDS 2021;National institutes of Health 2020	
Inadequate access to health care	Office of Retirement and Disability Policy 2019	Office of Retirement and Disability Policy 2019; Respondent 8	
Inadequate access to pensions or social security	Office of Retirement and Disability Policy 2019	Office of Retirement and Disability Policy 2019; Respondent 8	
Injury to eyes: short term	World vision 2013		
Interpersonal or communal violence	Unicef 2019	GSS 2013 according to Schwartz et al. 2021; Elenge & De Brouver 2010	
Knee pain moderate			Jeripotula et al. 2020
Labor union restrictions	World vision 2013		
Low back pain, moderate	Elenge & De Brouver 2010		Jeripotula et al. 2020
LSM pit manager		MPSMRM 2014; World Food Programme 2020; Geenen et al. 2021	
LSM worker		MPSMRM 2014; World Food Programme 2020; Geenen et al. 2021	
Lung cancer metastatic	TTL 2021; American Cancer Society 2021; Tae-Woo et al. 2010; Wabinga et al. 2011; Chokunonga et al. 2011	Banza Lubaba Nkulu et al. 2009; TTL 2021; American Cancer Society 2021; Tae-Woo et al. 2010; Wabinga et al. 2011; Chokunonga et al. 2011; McCormack & Schüz 2011	TTL 2021; American Cancer Society 2021; Tae-Woo et al. 2010; Wabinga et al. 2011; Chokunonga et al. 2011

Mild silicosis	Yang & Yang 2006; McCormack & Schüz 2011	Yang & Yang 2006; McCormack & Schüz 2011	Yang & Yang 2006; McCormack & Schüz 2011
Moderate hearing loss	Gyamfi et al. 2016; Basu et al. 2015		Gyamfi et al. 2016
Moderate malaria		Basu et al. 2015	
Moderate silicosis	Yang & Yang 2006; McCormack & Schüz 2011		Yang & Yang 2006; McCormack & Schüz 2011
Mortality	Tsurukawa 2011; Elenge et al. 2013; Kyeremateng-Amoah & Clarke 2015		Stemn 2019
Muscoskeletal problems upper limb pain moderate	Elenge & De Brouver 2010		Jeripotula et al. 2020
Neck pain moderate			Jeripotula et al. 2020
Open wound: short term, with or without treatment	Elenge et al. 2013		Stemn 2019
Other drug use disorders	Elenge et al. 2013		
Other injuries of muscle and tendon (contusion)			Stemn 2019
Other musculoskeletal disorders severity level 1 (Leg pain)	Elenge & De Brouver 2010; World Vision		
Poisoning: short term, with or without treatment (copper)	World vision 2013		
Refugees or internally displaced		Kannah 2019; Amnesty International 2019	
Severe hearing loss	Gyamfi et al. 2016; Basu et al. 2015		Gyamfi et al. 2016
Severe motor plus cognitive impairment with blindness		Vaan Brusselen et al. 2020	
Severe silicosis without heart failure	Yang & Yang 2006; McCormack & Schüz 2011		
Skin irritation	World vision 2013; Elenge & De Brouver 2010		

Stressful working conditions	TTK 2015		TTK 2015
Symptomatic HIV with mild anemia		GSS 2013 according to Schwartz et al. 2021; UNAIDS 2021;National institutes of Health 2020	
Threats of violence or other contact crimes	Sovacool 2019; Katz-Lavigne 2020	GSS 2013 according to Schwartz et al. 2021; Elenge & De Brouver 2010	
YLL Birth defects		Vaan Brusselen et al. 2020	
YLL HIV		GSS 2013 according to Schwartz et al. 2021; UNAIDS 2021;National institutes of Health 2020	
YLL Lung cancer	TTL 2021; American Cancer Society 2021; Tae-Woo et al. 2010; Wabinga et al. 2011; Chokunonga et al. 2011		TTL 2021; American Cancer Society 2021; Tae-Woo et al. 2010; Wabinga et al. 2011; Chokunonga et al. 2011
YLL Malaria		Basu et al. 2015; WHO 2021a	

Duration/time allocation of different disabilities

Inventory duration and time allocation (Years)			
Inventory flow	DRC: Cobalt mining ASM	DRC: Cobalt mining community	DRC: Cobalt mining LSM
AIDS with mild anemia		3	
Alcohol problem use	42,7		
Amputation of finger, thumb or toe			42,7
ASM pit manager		42,7	
ASM worker		42,7	
Burns of <20% total surface area without lower airway burns: short term, with or without treatment			42,7
Child labor	6		
Children out of school		42,7	
Crime victim compensation		60,7	
Excessive work	42,7		42,7
Foot pain moderate			42,7
Fracture of patella, tibia or fibula, or ankle: short term,with or without treatment	42,7		
Fracture of radius or ulna: short term, with or without treatment	42,7		
Gender related participation restrictions		45,7	
General fracture			42,7
Headache: tension-type	42,7		
Hearing loss: mild	42,7		42,7
Hip pain moderate			42,7
HIV/AIDS cases, receiving ARV treatment		40,7	
Inadequate access to health care	42,7	60,7	
Inadequate access to pensions or social security	42,7	60,7	
Injury to eyes: short term	Child: 48,7		
Interpersonal or communal violence	42,7	Child: 18 Woman: 42,7	
Knee pain moderate			42,7

Labor union restrictions	42,7		
Low back pain, moderate	42,7		42,7
LSM pit manager		42,7	
LSM worker		42,7	
Lung cancer metastatic	1	0,7	1
Mild silicosis	12,5	0,7	12,7
Moderate hearing loss	42,7		42,7
Moderate malaria		5	
Moderate silicosis	Child: 9 Adult: 7,3		Adult: 7,3
Mortality	35,7		22,7
Muscoskeletal problems upper limb pain moderate	42,7		42,7
Neck pain moderate			42,7
Open wound: short term, with or without treatment	42,7		42,7
Other drug use disorders	42,7		
Other injuries of muscle and tendon			42,7
Other musculoskeletal disorders severity level 1 (Leg pain)	Adult: 42,7 Child: 48,7		
Poisoning: short term, with or without treatment	Child: 48,7		
Refugees or internally displaced		60,7	
Severe hearing loss	42,7		42,7
Severe motor plus cognitive impairment with blindness		1	
Severe silicosis	Child: 4,3		
Skin irritation	Adult: 42,7 Child: 48,7		
Stressful working conditions	42,7		42,7
Symptomatic HIV with mild anemia		5	
Threats of violence or other contact crimes	42,7	Child: 18 Woman: 42,7	
YLL Birth defects		59,7	
YLL HIV		27,7	
YLL Lung cancer	Adult: 18,9 Child: 24,9		18,9
YLL Malaria		55,7	

Results per process

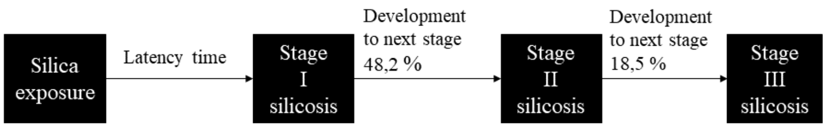
ASM		
Impact	Total Damage	% of full wellbeing
Value of full well-being before impacts	1,89E-03	100 %
Mortality	2,81E-05	1,49 %
Non-lethal health impacts	4,90E-04	25,92 %
Autonomy infringements	3,99E-04	21,11 %
Anxiety	6,80E-04	36,00 %
Unequal opportunities	0,00E+00	0,00 %
Participation restrictions	1,89E-04	10,00 %
Current level of wellbeing	1,03E-04	5,48 %

LSM		
Impact	Total Damage	% of full wellbeing
Value of full well-being before impacts	2,11E-04	100 %
Mortality	1,10E-06	0,52 %
Non-lethal health impacts	2,56E-05	12,12 %
Autonomy infringements	2,11E-05	10,00 %
Anxiety	9,50E-06	4,50 %
Unequal opportunities	0,00E+00	0,00 %
Participation restrictions	0,00E+00	0,00 %
Current level of wellbeing	1,54E-04	72,85 %

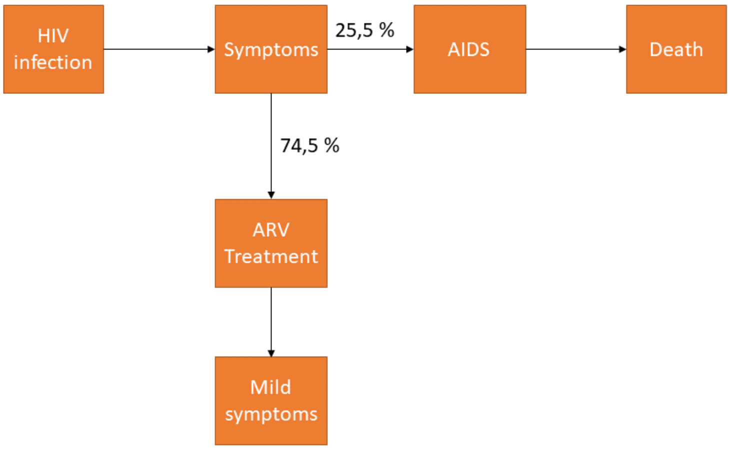
Local community		
Impact	Total Damage	% of full wellbeing
Value of full well-being before impacts	2,94E-02	100 %
Mortality	9,42E-04	3,20 %
Non-lethal health impacts	2,85E-04	0,97 %
Autonomy infringements	1,69E-04	0,57 %
Anxiety	1,45E-04	0,49 %
Unequal opportunities	2,24E-03	7,61 %
Participation restrictions	4,27E-04	1,45 %
Current level of wellbeing	2,52E-02	85,70 %

Disease models

Silicosis disease model



HIV disease model



Data quality

Data quality was reviewed by using data quality assessment matrix by Life Cycle Initiative (2020) (table 9-11). The data quality was assessed in scale from 1 to 5. Sensitivity check was not performed because there were too many uncertainties in the data for it to be useful. Abbreviations used in checks are following:

- R: reliability of sources
- C: completeness conformance
- T: temporal conformance
- G: geographical conformance
- F: Further technical conformance

The temporal conformance was set to 10 years since there has not been implemented changes in mining systems in last 10 years even though the legislation has been revisited recently. Most of the sources are rated by reliability and consistency score 2 since the data comes from one source and the sampling of the data is small. Many assumptions are also made due to lack of exact data from large studies. Geographical conformance is mostly from DRC, but some data considering occupational and communal diseases are from Ghana, India and Turkey, which could be assumed to have similar working regulations to DRC. The technology considering ASM and LSM considering these countries is assumed to be similar to DRC.

ASM data quality					
Flow	**R**	**C**	**T**	**G**	**F**
Alcohol problem use	Score 1	Score 2	Score 1	Score 1	Score 1
Child labor	Score 2	Score 1	Score 1	Score 1	Score 1
Excessive work	Score 2	Score 3	Score 1	Score 1	Score 1
Fracture of patella, tibia or fibula, or ankle: short term,with or without treatment	Score 1	Score 2	Score 1	Score 1	Score 1
Fracture of radius or ulna: short term, with or without treatment	Score 1	Score 2	Score 1	Score 1	Score 1
Headache: tension-type	Score 2	Score 2	Score 2	Score 1	Score 1
Hearing loss: mild	Score 1	Score 2	Score 1	Score 2	Score 2

Inadequate access to health care	Score 3	Score 2	Score 1	Score 1	Score 1
Inadequate access to pensions or social security	Score 3	Score 2	Score 1	Score 1	Score 1
Injury to eyes: short term	Score 2	Score 4	Score 1	Score 1	Score 1
Interpersonal or communal violence	Score 1	Score 1	Score 1	Score 1	Score 5
Labor union restrictions	Score 3	Score 4	Score 1	Score 1	Score 1
Low back pain, moderate	Score 1	Score 2	Score 2	Score 1	Score 1
Lung cancer metastatic	Score 3	Score 2	Score 1	Score 2	Score 2
Mild silicosis	Score 3	Score 2	Score 1	Score 2	Score 2
Moderate hearing loss	Score 1	Score 2	Score 1	Score 2	Score 2
Moderate silicosis	Score 3	Score 2	Score 1	Score 2	Score 2
Mortality	Score 1	Score 2	Score 1	Score 1	Score 1
Muscoskeletal problems upper limb pain moderate	Score 1	Score 2	Score 2	Score 1	Score 1
Open wound: short term, with or without treatment	Score 1	Score 2	Score 1	Score 1	Score 1
Other drug use disorders	Score 1	Score 2	Score 1	Score 1	Score 1
Other musculoskeletal disorders severity level 1 (Leg pain)	Score 1	Score 2	Score 1	Score 1	Score 1
Poisoning: short term, with or without treatment	Score 2	Score 4	Score 1	Score 1	Score 1
Severe hearing loss	Score 1	Score 2	Score 1	Score 2	Score 2
Severe silicosis without heart failure	Score 3	Score 2	Score 1	Score 2	Score 2
Skin irritation	Score 1	Score 2	Score 1	Score 1	Score 1
Stressful working conditions	Score 2	Score 2	Score 1	Score 1	Score 1
Threats of violence or other contact crimes	Score 3	Score 3	Score 1	Score 1	Score 1
YLL Lung cancer	Score 3	Score 2	Score 1	Score 2	Score 2

LSM data quality					
Flow	**R**	**C**	**T**	**G**	**F**
Amputation of finger, thumb or toe	Score 1	Score 2	Score 1	Score 1	Score 2
Burns of <20% total surface area without lower airway burns: short term, with or without treatment	Score 1	Score 2	Score 1	Score 1	Score 2
Excessive work	Score 2	Score 2	Score 1	Score 1	Score 2
Foot pain moderate	Score 1	Score 2	Score 1	Score 1	Score 2
General fracture	Score 1	Score 2	Score 1	Score 1	Score 2
Hearing loss: mild	Score 1	Score 2	Score 1	Score 1	Score 2
Hip pain moderate	Score 1	Score 2	Score 1	Score 1	Score 2
Knee pain moderate	Score 1	Score 2	Score 1	Score 1	Score 2
Low back pain, moderate	Score 1	Score 2	Score 1	Score 1	Score 2
Lung cancer metastatic	Score 3	Score 2	Score 1	Score 3	Score 2
Mild silicosis	Score 3	Score 2	Score 1	Score 1	Score 2
Moderate hearing loss	Score 1	Score 2	Score 1	Score 1	Score 2
Moderate silicosis	Score 3	Score 2	Score 1	Score 1	Score 2
Mortality	Score 1	Score 2	Score 1	Score 1	Score 2
Muscoskeletal problems upper limb pain moderate	Score 1	Score 2	Score 1	Score 1	Score 2
Neck pain moderate	Score 1	Score 2	Score 1	Score 1	Score 2
Open wound: short term, with or without treatment	Score 1	Score 2	Score 1	Score 1	Score 2
Other injuries of muscle and tendon	Score 1	Score 2	Score 1	Score 1	Score 2
Severe hearing loss	Score 1	Score 2	Score 1	Score 1	Score 2
Stressful working conditions	Score 2	Score 2	Score 1	Score 1	Score 2
YLL Lung cancer	Score 3	Score 2	Score 1	Score 3	Score 2

Local community data quality					
Flow	**R**	**C**	**T**	**G**	**F**
AIDS with mild anemia	Score 3	Score 3	Score 1	Score 1	Score 2
ASM pit manager	Score 3	Score 2	Score 1	Score 1	Score 1
ASM worker	Score 3	Score 3	Score 1	Score 1	Score 1
Children out of school	Score 1	Score 1	Score 1	Score 1	Score 1
Crime victim compensation	Score 3	Score 2	Score 1	Score 1	Score 1
Gender related participation restrictions	Score 3	Score 3	Score 1	Score 1	Score 1
HIV/AIDS cases, receiving ARV treatment	Score 3	Score 3	Score 1	Score 1	Score 2
Inadequate access to health care	Score 3	Score 2	Score 1	Score 1	Score 1
Inadequate access to pensions or social security	Score 3	Score 2	Score 1	Score 1	Score 1
Interpersonal or communal violence	Score 3	Score 3	Score 1	Score 1	Score 1
LSM pit manager	Score 3	Score 3	Score 1	Score 1	Score 1
LSM worker	Score 3	Score 3	Score 1	Score 1	Score 1
Lung cancer metastatic	Score 3	Score 3	Score 1	Score 3	Score 2
Mild silicosis	Score 3	Score 2	Score 1	Score 1	Score 2
Moderate malaria	Score 3	Score 3	Score 1	Score 1	Score 2
Refugees or internally displaced	Score 3	Score 2	Score 1	Score 1	Score 1
Severe motor plus cognitive impairment with blindness	Score 2	Score 1	Score 1	Score 1	Score 1
Symptomatic HIV with mild anemia	Score 3	Score 3	Score 1	Score 1	Score 2
Threats of violence or other contact crimes	Score 3	Score 3	Score 1	Score 1	Score 1
Yll Birth defects	Score 2	Score 2	Score 1	Score 1	Score 1
YLL HIV	Score 3	Score 3	Score 1	Score 1	Score 2
YLL Malaria	Score 3	Score 3	Score 1	Score 1	Score 2