Public health and mining in East and Southern Africa: A desk review of the evidence

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Executive summary

The mining industry is a critical contributor to economic growth in East and Southern Africa (ESA), providing incomes and employment. However, mining also imposes health consequences for workers, ex-miners and communities. The expansion of mining has brought public health challenges given the physical, chemical, biological, ergonomic and social hazards involved. The extent of the health risks and the affected population depends on the type of mining and how far standards are met. As mining sites tend to be isolated, mining communities experience social exclusion. The communities living around mines tend to be poor, with limited access to health and other services. While work is underway to address HIV, tuberculosis (TB) and some occupational health risks, it is important to fully understand the scope of these health challenges to better control them.

This desk review was commissioned by the Regional Network for Equity in Health in East and Southern Africa (EQUINET) through Training and Research Support Centre, as part of the ongoing work in EQUINET on the extractive sector in the region. It aims to inform public sector professionals, policy-makers, civil society and parliamentarians on the population health impacts of large- and small-scale mining activities in East and Southern Africa. It presents evidence of the documented health outcomes of mining in ESA countries and gaps between what is known of health risks of mining and these documented outcomes.

The desk review included secondary grey and published documents in English from online databases, country and international organisation websites. As a limitation, literature not available online was not included. Some ESA countries have more information than others and some minerals are more studied than others and documents in other languages were not captured.

Large- and small-scale mines are involved with extraction of diamonds, oil, gold, copper, iron ore, nickel, coal, cobalt, diamond, limestone, fossil fuel, gemstones, chrome, uranium, graphite, bauxite, zinc, platinum, manganese, vanadium, vermiculite, palladium, ilmerite, rutile, zirconium, aluminium, clay, gypsum, asbestos, tanzanite, salt, phosphates, silver and rhodium. Artisanal small-scale mining (ASM) in the ESA region is widespread, with the number of ASM workers not known but likely to be higher than those working in large-scale mines. ASM is associated with poorly regulated activities, child labour and poor occupational safety and health. Large- and small-scale mining has been associated with both acute and long-term health effects on miners, ex-miners and communities. Mining-related displacement or resettlement of communities has led to loss of livelihood and access to health and other social services.

The health hazards from mining arise from mining itself, processing and handling of mine products, mine waste management and post-mine closure exposures. Health outcomes depend on the type of minerals mined, the duration, level of exposure, background health status of mineworkers and work place occupational, safety and health (OSH) standards implemented. Known diseases related to mine work include, for example, silicosis and TB in gold and platinum mines; pneumoconiosis in coal mines; asbestosis, lung cancer, mesothelioma in diamond mines; cancers and haematological damage in uranium and iron ore mines.

The paper specifies the known health risks for each type of mining in the ESA region. Mine operations can generate noise-induced hearing loss (NIHL) in workers, with the severity depending on the age of the miner, type of mining and years of exposure. There are also risks of excessive heat exposure, fatigue and stress among miners. When parents are exposed to toxic heavy metals there are potential health hazards for newborns, and mine hazards such as lead can affect child development.

These risks, injuries and deaths have been reported in both small- and large-scale mines, with gender, income and race disparities in health impacts direct and indirect. Poor communities are likely to be more affected as they have limited choices for employment, suboptimal housing and limited access to safe drinking water.

People living close to mining sites or near mine dumps and those whose livelihoods are tied to rivers for domestic and agriculture water are exposed to polluted environments due to mining wastes and contaminated air and drinking water. These communities consume fish from contaminated rivers or grow crops in contaminated soils, ingesting toxins in their diets. School children who attend classes close to mining areas may be exposed to dust particles and chemicals that affect brain development and long-term risks, such as the risk of developing cancers as adults. Displacement of people by mining operations without adequate infrastructure and services leads to loss of livelihoods and poor living conditions.

Discrepancies exist between what is documented and known about the health risks of mining globally and documented levels of these health outcomes in the ESA region. There are various reasons for this. Health impacts assessments are not always done before mines are licensed. After mines are licensed, these health outcomes may be poorly monitored. Information on the numbers and health status many living and working in mining and of ex-miners remains limited. Permissible exposure levels (PELs) for toxins/ dusts may not be set at adequate levels to prevent disease, may be outdated or inappropriate for the country context.

Mines may not take on the long-term health risks as ex-miners return to home communities with chronic illness and burden communities, which have no capacity to manage these conditions. The compensation systems for miners affected by chronic illnesses are often inaccessible or late, and while there is greater current attention to silicosis, many other long-term health conditions suffered by ex-miners are not detected, due to weak post-employment surveillance.

Information sometimes depends on specific surveys, but some minerals are more studied than others, as are some countries and risk groups. Occupational health standards, laws and codes themselves have gaps and may be poorly enforced. The number of people working in ASMs is not well known and there is limited surveillance of their health risks. Weak or non-existent medical surveillance programmes, lack of demographic site surveillance systems, outdated or inappropriate OSH standards for different exposures, lack of standards for non-occupational exposure limits and lack of information on permissible exposure limits for certain compounds all contribute to deficits in available information.

Notwithstanding the under-reporting of health risks in the region, the evidence in this paper suggests diverse, wide-ranging and significant health impacts. The mining sector has an enduring presence in the region due to its economic significance and expanding both large and small-scale mining operations. This potentially expands the health risks. The impact of mining on the environment and on human health cannot thus be ignored. Although efforts made should be applauded, they are not yet sufficient to address the harms to health. Technological advances, regional collaboration and the improvement of human rights open opportunities to address these health risks of mining.

The public health consequences require innovative, cross-country and multidisciplinary approaches to have an effective and sustainable response that prevents, detects and manages these different health risks, including after mine closure. This depends on improving the availability of timely, quality information in a more systematic manner than ad hoc surveys to support the development of appropriate and improved public health interventions for miners, ex-miners and communities across the region.

1. Introduction

Mining in East and Southern African (ESA) is a critical driver of economic growth (ADB, 2018). The region contributes significantly to the global commodity output of metals, gemstones, nuclear and fossil fuels (Loewenson et al., 2016; Milesi, 2006; World Bank, 2014). The main commodities mined in the region include gold, diamonds, copper, coal, iron, manganese, platinum, zinc, uranium, chromium, sand and clay stone (TIMS Baseline Report n.d; Loewenson et al., 2016). The mineral deposits present an employment opportunity and are a major source of export earnings. In the Southern African Development Community (SADC) region alone, the mining sector accounts for 10% of the gross domestic product (GDP) and 60% of foreign exchange earnings for the member states (SADC, 2012). Due to the importance of the mining sector to the SADC region, a Protocol on Mining was launched in September 1997 and effected in February 2000. The protocol requires that member states uphold health, safety and environmental protection standards (SADC Protocol on Mining, 1997).

Public health is recognised as a key factor in ensuring inclusive social development in the region. Nevertheless many ESA countries face challenges to public health. Mineworkers exposed to various hazards during mine operations experience poor health outcomes, and mining communities suffer health consequences of poverty, food insecurity, hazardous working conditions, poor environments and loss of biodiversity (Ehrlich et al., 2018; Nelson, 2013; Churchyard et al., 2004; Asare and Darkoh, 2001; MoH/EQUINET, 2018).

SADC and the United Nations Economic Commission for Africa (UNECA) called for harmonisation of policies and standards in member states to enforce uniform health, safety and environmental guidelines (SADC/UNECA, 2009). Realising that some of the public health risks can be prevented, some health-related projects are being implemented in the ESA region, including:

a) The Southern Africa Tuberculosis and Health System Support Project (SATBHSS), which aims to strengthen response to TB and occupational lung diseases in Lesotho, Malawi, Mozambique and Zambia.
b) The East Africa Public Health Laboratory Network (EAPHLN) focusses on controlling the spread of communicable diseases in East Africa through improved diagnostics and surveillance capabilities in Kenya, Uganda, Tanzania, Rwanda and Burundi.
c) The TB in the Mines Sector in Southern Africa (TIMS) addresses a regionally co-ordinated response to TB and related illnesses among mineworkers, ex-mineworkers and their families and communities. All SADC member states are implementing it.

Despite these policy intentions, institutional arrangements and actions, member states still face challenges in reducing mining-related public health issues (MoH Zambia and EQUINET, 2018).

EQUINET, through TARSC and other institutions in the region in an Extractives and Health Group, has implemented research and policy engagement on extractive industries/mining and health. The network has reviewed international and national laws and standards as a basis for proposals on regional guidance on mining and health and prepared health literacy materials on mining and health for workers, communities and ex-mineworkers. As a follow up, this desk review commissioned by EQUINET seeks to inform public sector professionals, policy-makers, civil society and parliamentarians on the population health impacts of the large- and small-scale mining activities in ESA countries. It presents evidence of the documented health outcomes of mining in ESA countries and gaps between what is known of health risks of mining and these documented outcomes.

The desk review drew information from online searches in PubMed Central (PMC), Google Scholar, World Bank publications, SADC publications, Chambers of Mines, country profiles, International Labour Organisation (ILO) website and other relevant international organisation websites. Both grey and published literature was reviewed, including studies and data on the distribution and determinants of health outcomes of different mining activities in the region. While a substantive body of literature was found, with 214 papers cited in this paper, there were also limitations: Only papers in English were included, potentially under-representing lusophone and francophone countries, viz: Angola, Mozambique and the Democratic Republic of Congo (DRC). Grey literature not available online was not included. The studies were of variable quality, sometimes old, and concentrated in particular countries and on particular risks. Countries with wide and varied mineral deposits were more likely to have a wide range of information. Nonetheless, scientific evidence for the ESA region was adequate to identify major health patterns.

2. Mining in the region

2.1 Types of mining

Mining can generally be categorised as large or small scale. Mining operations can be open pit - extracting minerals near surface layers; surface mining - excavating or stripping soil to acquire minerals in shallow deposits; underground mining - digging shafts and tunnels to reach deeper deposits; placer mining - sifting out metals from sediments in rivers and beaches; and in-situ mining - dissolving minerals in place and then processing them at the surface without moving rock from the ground (ELAW, 2020). The form of mining is determined by the type of mineral extracted, its location relative to the earth's surface and the value of the mineral. Each method impacts on both environment and health. As resources closer to the surface are depleted, deeper mining may be expected, with associated risks (Gibb and O'Leary, 2014).

The profile of mineral resources in the region are shown in *Table 1*:

Table 1: Mining in selected ESA countries

Country (population)	Types of large-scale mining	Types of small-scale mining
Angola (32,866,272)	Diamond, oil, gold, copper	Iron ore
Botswana (2,254, 130)	Diamond, gold, nickel, copper, coal	Coal, iron ore
Democratic Republic of Congo (84,068,090)	Copper, diamond, cobalt, gold	Cobalt
Kenya (51, 393,010)	Copper, gold, limestone, fossil fuel	Gold, gemstones
Lesotho (2,108,130)	Diamond, sandstone	Diamond
Madagascar (26,262,370)	Chrome, cobalt, nickel	Gold, gemstones
Malawi (18,143,310)	Coal, uranium, limestone	None
Mauritius (1,265,300)	None	None
Mozambique (29,495,960)	Gold, graphite, boxite	Coal, Gold
Namibia (2,448,260)	Copper, diamond, uranium, zinc, gold	Copper, diamond
South Africa (57,779,620)	Coal, chrome, gold, diamond, iron ore, platinum, manganese, vanadium, vermiculite, palladium, ilmerite, rutile, zirconium	Copper, zinc, uranium, aluminium, nickel, lead, cobalt, iron, clay, limestone, gypsum
Swaziland (1,136,190)	Diamonds, asbestos, coal	Diamond
Tanzania (56,318,350)	Gold, diamond, tanzanite, salt, phosphates, silver, copper, cobalt	Mercury, nickel, coal, gold, diamond
Uganda (42,622,520)	Gold, copper	Cobalt, gold, clay
Zambia (17,351,820)	Copper, cobalt, gold, selenium, iron ore, emeralds	Gold, nickel, iron ore, coal, gemstones
Zimbabwe (14,439,020)	Coal, diamonds, chrome, gold, platinum, nickel	Copper, iron ore, gold, silver, rhodium, coal, chrome

Sources: MiningIQ, https://eiti.org/madagascar#production; EARF, 2018; Loewenson, 2018; Loewenson et al., 2016; TIMS Baseline Report n.d; World Bank, 2014; 2018.

Other countries like Swaziland, Lesotho and Mozambique are major labour-sending countries to South Africa, and they experience the burden of poor health in former mineworkers who worked in the mines of South Africa. South Africa, Zambia, DRC, Tanzania and others have largely national mineworkers migrating from each of the sub-regions/provinces in the country. South Africa harbours both in country and cross-country labour migration (World Bank, 2014).

2.2 Populations living and working in mining areas

The total population of formal/large-scale miners in the ESA region is estimated to be between 3-4 million (TIMS n.d; EARF, 2018). In the SADC region, an estimated 5% of the population is employed in the formal mining sector, varying across countries (SADC, 2012). Between 2008-2012, there were about 569,813 miners in South Africa alone, based on The Employment Bureau of Africa (TEBA) records, the majority of whom were employed in gold mines (53%) followed by 32% in platinum and 2.4% in coal mines. Over 90% were black males working underground or on risky surfaces. Of the labour-sending countries to South Africa, the majority of mineworkers come from Lesotho (13%), followed by Mozambique (9%) and the least from Swaziland. The decline in gold mine employment levels was noted to imply that many workers with silicosis are now in the communities or remaining as ‘illegal’ or undocumented immigrants resident in recipient countries (Ehrlich et al., 2018). This situation and the unwillingness of undocumented migrants to be detected at health services raises the risk of diseases such as TB spreading the surrounding populations, undermining disease control efforts.

The ESA region has a large artisanal small-scale mining (ASM) sector, particularly in Zimbabwe (about 400,000 miners), Namibia (83% of all miners), Uganda (90% of all miners) and Tanzania (>1,000,000 miners) (TIMS n.d.; EARF, 2018). Information on the ASM population is either incomplete or missing for other ESA countries, so that the total number of people involved in ASM is unknown, although with indications that their numbers exceed those working in large-sector mines (EARF, 2018). ASM communities are largely low income, mobile, with low literacy and unlicensed operations, with limited information on their employees and disease burden (TIMS n.d.).

Displacement is common for large-scale mines. The resettlement of displaced communities is often haphazard and at the mercy of investors who, in many cases lack, resettlement action plans (Abuya, 2016; Chu et al., 2015). While displacement in Europe largely arises due to large-scale open-pit mining, in Africa, people are displaced in weak regulatory contexts (Terminski, 2012; EJA, 2019; Chu et al., 2015; Lillywhite et al., 2015; Kesselring, 2018). In Mozambique’s Tete province more than 7,000 residents were reported to be affected due to approximately 3.4-6 million hectares of land earmarked for mining explorations (EJA, 2019). Discontent in and unrest in affected communities in Tete led to one death and several protests, with the stress of resettlement having long-term effects on these communities. This situation is exacerbated by power imbalances between local and international stakeholders (Wiegnik, 2018; Lillywhite et al., 2015).

In rural South Africa, large-scale mining has the potential to increase poverty and reduce access to agricultural produce by displacing people to less fertile land, with negative consequences for nutrition and mental stress (Mtero, 2017). A large-scale diamond mine in Angola is reported to have contributed to inequalities through displacement of local communities, communities who could not subsequently access jobs, housing and water, leading to ongoing contestations with urban planners and private firms, raising concern on how communities are involved in and give prior consent to resettlement planning (Rodrigues, 2017). Mine-related conflicts are found to be reduced by consultation with affected communities, measures to minimise disruptions to livelihoods and ensuring access to health, safety, housing, agricultural land and other services (Loewenson and Simpson, 2015; Obiri et al., 2016; Abuya, 2016). Mining poses both present and future challenges to miners and their families, such as in Zambia and South Africa where even after mines closure, communities living around mining towns are exposed to risks associated with mining, discussed later (Mwaanga et al., 2019; Bose-O’Reilly et al., 2018; Ngole-Jeme and Fantke 2017; Obiri et al., 2016).

2.3 Ex-mineworkers

Ex-miners are those who were employed as a miner, whether full time, in short contracts or as casual employees (World Bank, 2014). The exact number of ex-miners in the ESA region is unknown as they are poorly tracked post-employment across their countries of origin, an issue that undermines effective planning for their wellbeing (Ehrlich et al., 2018; World Bank, 2015). A 2015 WB report, estimated about 2,000 000 ex-miners alive and living with TB or at risk of TB in Southern Africa **(**World Bank, 2015).

Migrant mine work has been prevalent in South Africa since the early colonial period, with most coming from Lesotho, Swaziland and Mozambique (World Bank, 2014; 2015). In Zambia, migrant mineworkers were removed from the mines after independence through a process called 'Zambianisation' (Money, 2019). Recruitment to South African mines has changed over time, with fewer gold miners, more female miners, a shift from migrant to local employees and changes from full-time to contractual employment (Ehrlich et al., 2018; World Bank, 2015). This is observed to have led to

> … *externalisation of the burden of mining lung disease to home communities, as miners, particularly from the gold sector, leave the industry. The implications for health, surveillance and health services of the growing number of miners hired as contractors need further research, as does the health experience of female miners*. (Ehrlich et al., 2018)

3. Health risks related to mining

Mining communities are often isolated, suffer social exclusion, live far from homes, social networks and families, often in other ESA countries (ELAW, 2020; World Bank, 2015). In such situations they often live in 'mining shanties' as dwellings for migrant mineworkers, with poor living conditions, limited access to safe water and sanitation, surrounded by poor communities and with poor social conditions, crime, violence, including alcohol and drug abuse and risky sexual behaviour. This has been linked to sexually transmitted diseases (STDs) and injury (World Bank, 2014; Asare and Darkoh, 2001; Steele et al., 2019). Those living close to mining sites are exposed to polluted air, soils and water, with mine dumps, slags and tailings a source of health hazards (Mwaanga et al., 2019; Rusibamayila et al., 2018; Ekosse et al., 2004; Mwandira et al., 2018; Mataba et al., 2016; Squadrone et al., 2016; Mshana, 2015).

The specific health outcome of the exposures depends on the mineral mined and exposure levels and duration and general health status of those exposed (Ross et al., 2004). More male than female miners and more black than white miners are likely to be employed for underground or manual operations (Ehrlich et al., 2018). In terms of socio-economic status, the poor are likely to suffer more as they have limited choices of employment, suboptimal dwelling/housing and access to safe drinking water. The poor labourers have their homesteads close to mining sites or near mine dumps (Asare and Darkoh, 2001). Mining involves digging up massive areas of land either on the surface or underground, thus generating a lot of particulate matter, aerosols, and dust particles of different sizes; metal contaminants; gases, chemicals and earth movements (Loewenson et al., 2016). Heavier and larger particles tend to settle close to the mining site, while smaller, fine dust particles are dispersed by wind to homes, schools, rivers and communities not directly involved in mining (Andraos et al., 2018; Maina et al., 2016; Diami et al., 2016; Ndilila et al., 2014; Wiseman and Zereini, 2009; Ekosse, 2005).

Dust particles or silicates cause various respiratory illnesses, including silicosis, TB, chronic obstructive pneumonia disease (COPD), pneumoconiosis, asthma, emphysema, asbestosis, lung cancer, mesothelioma and haematological damage Utembe et al., 2015; Nelson, 2011; 2013; Hudson-Edwards et al., 2011; Girdler-Brown et al., 2008; Naidoo et al., 2005; Chavez-Galan et al., 2013; Ndhlovu et al., 2018; Winde et al., 2004; Laney et al., 2012; Knight et al., 2015; Rees and Murray, 2007; Churchyard et al., 2004). Noise from mine operations causes noise-induced hearing loss (NIHL) with severity depending on age, type of mining and years of exposure (Musiba et al., 2015, Chadamuka et al., 2013). Miners also suffer excessive heat exposure, fatigue and stress (Pelders and Nelson, 2019; Meshi et al., 2018; Krainak, 2018). Occupational exposure to vibrations may lead to musco-skeletal injury, cardiovascular and gastrointestinal problems, often poorly documented (Krainak, 2018). Exposure of parents to toxic metals has also been linked to potential health hazards in newborns (Kayembe-Kitenge et al., 2019).

Mining processes are associated with disasters or accidents, with musco-skeletal, traumatic injury and death from falling rocks, lifting heavy equipment, landslides, flooding and sinkholes in large- and small-scale mines (Basu et al., 2015, Michelo et al., 2009; ILO, 1999; Nyanza et al., 2019; Rees et al., 2010; Boniface et al., 2013; Kunda et al., 2013; Michelo et al., 2009). ASM workers have limited information on safety and lack or do not use personal protective equipment (PPEs) (Nyanza et al., 2017; Chupezi et al., 2009; Hilson et al., 2006; ILO, 1999).

Mining activities have negative spillover effects in communities through environments, foods and other routes. Hazards from minerals, contaminants, radioactive materials and mine waste pose environmental and health risks, exposing workers and surrounding communities (Utembe et al., 2015; Loewenson et al., 2016; Phakedi, 2010; Kamunda et al., 2016a; 2016b; Danjou et al., 2019; Righi et al., 2000). Communities whose livelihoods are tied to rivers for domestic and agriculture water are exposed to polluted water from mining wastes or slags, consume crops grown with polluted water or in contaminated soils or eat fish from contaminated rivers, compounding uptake of toxins (Green et al., 2019; Mwesigye et al., 2016; Nyanza et al., 2014a; 2014b; 2019; Mataba et al., 2016; Mshana, 2015; Squadrone et al., 2016; Maina et al., 2016).

School children who attend classes close to mining areas are exposed to dust particles and heavy metals that increase their risk of cancer as adults. They suffer emphysema, asthma, coughs and may have higher levels of heavy metal contaminants in their urine and blood. Poor neonatal development has been reported due to exposure to toxins during mothers' pregnancy or in breast milk, when pregnant women eat clay pieces and are exposed to toxic metals (Banza et al., 2009; 2018; Nkosi et al., 2017; Mohner et al., 2014; Dinocourt et al., 2015; Bose-O'Reilly et al., 2008a).

Abandoned or closed mines can be a source of contaminants long after mining operations cease. Higher levels of heavy metals have been found in blood, urine and milk samples of community members living near closed mines (Yabe et al., 2015; Plumlee et al., 2013; Bose-O'Reilly, 2008a; Bose-O'Reilly, 2008b). Community members living near artisanal cobalt mines had high levels of cobalt in blood and urine with evidence of genetic damage in children (Banza et al., 2014). Contaminants from closed mines and dumps have been associated with respiratory diseases, neurological disorders and skin disorders (Samiee et al., 2019; Bansa et al., 2017; Nyanza et al., 2014b; Kayembe-Kitenge, 2019; Bose-O'Reilly et al., 2008b).

Exposure to silica dust from mines has been documented to cause respiratory related diseases such as silicosis, tuberculosis, COPD and asthma (Ross and Murray, 2004; Rees and Murray, 2007). ESA countries have a high background prevalence of TB and HIV and silicosis compounds the problems with these co-infections (World Bank, 2014; Corbett et al., 2004; Hnizdo and Sluis-Cremer, 1993) Corbett et al., 2000). Reducing occupational exposure to silica dust is key to reducing TB among mineworkers because of the increased risk of TB from silicosis, HIV and silicosis/HIV together, especially as mining expands in high burden countries (Rees and Murray, 2007; Bell and Noursadegh, 2018; Gottesfeld et al., 2018). Even when mines implement interventions, miners may be re-infected from surrounding community members and vice-versa. Ex-miners experience a high risk of TB and silicosis (Hnizdo and Murray 1998; Churchyard, et al., 2014). Based on TEBA data estimates, 133,000 ex-miners could be living with a higher annual risk of TB given the high community background of TB, HIV infection and the accumulated silica dust exposure due to their employment history, weak post-employment surveillance and migration to home countries with weak health systems and surveillance and interruption of treatment (Ehrlich et al., 2018, Corbett et al., 2004; Park et al., 2009; World Bank, 2014).

Mining is itself a risk factor for TB. The prevalence of TB in the mines is about 30% among gold miners in South Africa; 65.4% among copper miners in Zambia; 30% among former gold miners in Lesotho and 27% among former miners in Botswana (Mathema et al., 2015; Steen et al., 1997; Ehrlich et al., 2018; Girdler-Brown et al., 2008; Mulenga et al., 2005). Mineworkers mix with non-miners in communities which, with frequent home visits for migrant workers, leads to transmission of TB beyond mining areas and spreading TB to surrounding communities and home communities, (Mathema et al., 2015, Rees et al., 2010; Ehrlich et al., 2018; Stuckler, 2011).

Wider economic and ecological trends interact with mining to affect health risks. Grayson and Watzman (2001) observed that as firms engage in deeper mining due to depletion of mineral reserves, working conditions become harsher and more risky, increasing health problems. Mining affects natural deforestation, soil erosion, water depletion/contamination and air pollution which in turn has negative impacts on climate, raising climate-related risks to health (Smith et al., 2014; Semenza and Menne, 2009).

The risks and health outcomes associated with the different types of mining in the ESA region as documented in international literature are summarised in *Table 2* below.

Table 2: Summary of documented risks and health outcomes by types of mining

Type of risk	Specific risks	Health outcomes	Found in
Physical (Noise, health, vibrating tools, dust/debris, etc)	High temperatures	Dehydration, renal impairment	Underground gold mining, copper and coal mining
	Noise	Noise induced hearing loss	Diamond, copper, gold and coal mining, Tanzanite, etc
	Dust particulate matter	Emphysema, coughs, pneumoconiosis, COPD, asthma, sore eyes	Coal, copper, gold and platinum mining
	Falling rock, handling heavy equipment, landslide, sinkholes, etc	Injuries, death	Underground gold, copper, coal, diamond and platinum mining
Chemical (Chemicals, radiation, gases, etc)	Radon inhalation Uranium dust	Lung cancer	Uranium mining
	Diesel particulate matter (DPM)	Cardiovascular dysfunction, asthma, neuro-inflammation, neurodegenerative diseases, nausea, headaches, lung cancer	All mining using gas/ petroleum for mining operations
	Mercury inhalation	Gastrointestinal problems, kidney damage, neurological disorders, mal-development in children	Artisanal small-scale gold mining
	Cyanide	Convulsions, unconsciousness, suffocation, pypoxia, cyanosis	Gold mining
	Arsenic	Cancer	Gold, iron ore and zinc mining

Type of risk	Specific risks	Health outcomes	Found in
	Silica dust	Respiratory diseases such as silicosis, TB, COPD, lung cancer , silico-TB, progresive massive fibrosis	Gold, copper and coal mining
	Iron ore (oxidated particulate matter)	Cancer	Iron ore mining and processing, zinc mining
	Carbon, nitrogen	Lung diseases, cardiovascular diseases, burns	Coal mining
	Platinum	Asthma, cutaneous eruptions, etc	Coal mining
	Sulphur dioxide	Respiratory diseases	Copper mining and refineries
	Coal dust	Pneumoconiosis	Coal mining
	Asbestos	Asbestosis, lung cancer, mesothelioma	Diamond mines
	Chromium	Lung cancer	Chrome and coal mining
Biological (Infectious agents, zoonoses etc)	*Mycobateria tuberculosis bacilii* (MTB)	TB	Gold and copper
	HIV	HIV/AIDS	Gold and copper mining
	Viruses	Viral haemorrhagic fevers (VHF)	Underground mining
	Cholera vibrio	Cholera	Mining sites
Ergonomic	Handling heavy equipment	Injury	All types of mining
	Long working hours	Injury, stress	All types of mining
Psychosocial	Long working hours	Injury, death, stress	All types of mining
	Heavy loads	Injury, death	All types of mining
	Harsh working conditions	Stress, alcoholism	All types of mining
	Sexual violence	Trauma, STIs,	All types of mining
	Crime	Trauma, deaths	All types of mining
	Drug abuse	Drug dependency syndrome	All types of mining
	Alcohol abuse	Alcohol dependency, violence, death	All types of mining
Other Accident and injury	Explosives	Injury, deaths	Copper, gold and coal mining
	Landslides	Injury, deaths	Underground; open pit mining
	Mudslides	Injury, deaths	Underground; open pit mining
	Flooding	Injury, deaths	Underground mining

Sources: Asare and Darkoh, 2001; Basu et al., 2009; 2015; Blackley et al., 2018; Bugarski et al., 2014; Calverley and Murray, 2005; Cohen et al., 2008; Cui et al., 2015; Diami et al., 2016; Esdaile and Chalker, 2018; Gottesfeld et al., 2015; Haney et al., 2012; Hayumbu et al., 2008; Lane et al., 2019; Levesque et al., 2011; Mabila et al., 2020; Mauderly, 2001; Meenakshi et ri et al., 2010; al., 2017; Michelo et al., 2009; Mulenga et al., 2005; Mwaanga et al., 2019; Naidoo et al., 2005; Naicker et al., 2003; Nelson, 2011; Ngosa and Naidoo, 2016; Park et al., 2004; Park and Zheng, 2012;Paruchuri et al., 2010; Pelders et al., 2019; PHSATSDR, 1999; Proctor et al., 2016; Soltani et al., 2018; Steele et al., 2019; Wild et al.,2009; Wiseman and Zereini, 2009; Wu et al., 2017; Zhang et al., 2016.

The next subsections discuss some of these risks found in the international literature for the different types of mining in the region. *Section 4* later explores the extent to which these risks are documented in the region.

3.1 Health risks of gold mining and mercury

Large-scale gold mines expose miners to respirable silica that leads to silicosis within the first 5 years of employment if dust control measures are not implemented and raise the risk of tuberculosis (TB) (Basu et al., 2009, Ehrlich et al., 2018; Verma et al., 2014, Churchyard et al., 2004; Nelson, 2013; Gottesfeld et al., 2018). The risk of TB may be exacerbated by crowded living conditions and conditions such as HIV that compromise immune systems, as well as by reactivation of latent TB among formerly treated individuals (Corbett et al., 2000). Gold mine tailings contaminate surrounding areas with arsenic, chromium and nickel that may be inhaled, accumulate on the skin, consumed in crops grown on contaminated soils or in contaminated water, and radioactive materials that raise the risk of cancer (Banza et al., 2009; Nyanza et al., 2014a; 2014b; Winde et al., 2004a; 2004b; 2019; Ngole-Jeme and Fantke, 2017, Winde and Sandham, 2004; Kamunda et al., 2016a; Danjou et al., 2019). The use of cyanide in gold extraction poses health risks to both miners and their communities either by accidental ingestion or dermal exposure (Obiri et al., 2006).

Mercury pollution is a global issue because of its widespread use in ASM (Esdaile, 2018; Gottesfeld et al., 2015, Gibb et al., 2014). Miners are exposed to mercury levels through amalgam (gold alloy) burners (Basu et al., 2015; Paruchuri et al., 2010). Mercury causes gastrointestinal symptoms when ingested, accumulates in the kidney and produces kidney damage and causes neurological damage when inhaled (Park and Zheng, 2012; PHSATSDR, 1999). In communities, contamination by mercury in water and soil accumulates in foods and causes physical and mental disability and poor development in children. Due to the proliferation of use of mercury in ASM, many people are exposed, with over 100 million people affected globally and women and children most vulnerable (Basu et al., 2015). Given its hazardous nature, efforts are being made to discourage the use of mercury in gold extraction (UNEP, 2017).

3.2 Health risks of coal mining

Dust generated in coal mining has caused pneumoconiosis among coal mineworkers, with the prevalence varying from 6% to 30%, with the variation due to differences in exposure duration, dust control measures implemented, demographic characteristics, individual susceptibility work type and research methods (Naidoo et al., 2005, Cui et al., 2015, Blackley et al., 2018; Almberg et al., 2018; Laney et al., 2012). In Britain, miners working in conditions considered safe (dust limit of 2mg/m3) were found to still be at risk of developing pneumoconiosis (Attfield, 1992). In the US, the risk and prevalence of coal worker pneumoconiosis was found to be higher among smaller than larger coal mines (Blackley et al., 2014). Exposure to high dust concentrations and other particulates has been known to cause emphysema among coal miners and other respiratory diseases (Mabila et al., 2019; Almberg et al., 2018; Cohen et al., 2008; Naidoo et al., 2005).

3.3 Health risks of copper, iron ore and platinum mining

Copper mining is associated with injuries and fatalities, particularly among underground workers, with rock falls responsible for most of the fatalities and injuries mainly from tools (Michelo et al., 2009). Health hazards in copper mining also arise from exposure to silicates during extraction and from sulphur dioxide fumes during smelting (Mwaanga et al., 2019). Respirable dust from copper mines contains crystalline silica exposing miners to a risk of silicosis, TB and COPD (Hayumbu et al., 2008; Ngosa and Naidoo, 2016). Copper mining also contaminates agricultural soils, with risk to children, even more than adults (Li et al., 2020; Antisari et al., 2019; Kumar et al., 2019). People living near and around copper mining areas tend to have elevated concentrations of heavy metals in their toenails compared to those from non-mining areas (Ndilila et al., 2014).

Workers in iron ore mines are at risk of exposure to oxidative particulate matter during mining and processing and exposure to iron ore dust increases the risk of lung cancer (Soltani et al., 2018; Wild et al., 2009, Chau et al., 1993). Iron ore mining leads to exposure to heavy metal contaminants near and around mining sites, including higher arsenic levels through ingestion, dermal and inhalation leading to a cancer risk in children (Diami et al., 2016). The inhaled mineral ores have a long latency period, calling for ongoing surveillance to establish the outcomes among those exposed (Soltani et al., 2018). In small-scale zinc mining, children were found to have higher non-carcinogenic risk than adults, but both were at risk even at low contamination levels (Wu et al., 2017).

Platinum compounds induce hypersensitivity, with allergic symptoms, cutaneous eruptions, severe asthma and skeletal deformities (Calverley et al., 1995; Pawlak et al., 2014; Roshchin et al., 1984; Stahler et al., 2013). Platinum sensitivity has been detected among platinum refinery workers and through environmental exposure among communities (Calverley and Murray, 2005; Wiseman and Zereini, 2009). Sexual violence, especially among women and children, has been reported in a community with local and international migrants in platinum mining (Steele et al., 2019). Weak services and flawed compensation systems were also documented to harm the well-being of workers and communities on the mines (Cairncross et al., 2013).

3.4 Health risks of diamond, cobalt, manganese, vanadium, chrome and uranium mining

Limited information exists on risks associated with diamond mining. Where asbestos deposits occur close to diamond mines, diamond miners may be exposed to asbestos fibres, linked to asbestosis, lung cancer, and mesothelioma (Nelson et al., 2011).

Exposure to high doses of cobalt may affect the heart, lungs, blood and thyroid (Leyssens et al., 2017). Manganese is a neurotoxin that can also cause pulmonary emboli, bronchitis and impotence, with symptoms of chronic toxicity observed in children living in areas around open pit mines, where environmental exposure to manganese is high (Duka et al., 2011; Crossgrove and Zheng, 2004; Grandjean et al., 2014). Uranium causes neurotoxicity, radioactive toxicity and genetic changes in children, raising the risk of cancer in later life (Dinocourt et al., 2015; Kathren and Burkin, 2008). Radon inhalation from uranium mining can lead to lung cancer even at low levels of exposure (Meenakshi et al., 2017; Lane et al., 2019; Tomasek et al., 2008). Radiological risk and lung cancer were found to be high due to leaching of radioactive materials from abandoned uranium mine activities (Meenakshi et al., 2017; Winde et al., 2004a; 2004b). Vanadium is an occupation hazard (Sluis-Cremer and Du Toit, 1968).

Chromium is associated with the risk of cancer through occupational and environmental exposure, including in groundwater supplies (Haney et al., 2012; IARC, 1990; Tutu et al., 2008; Proctor et al., 2016; Zhang et al., 2016). The lifetime risk of dying from lung cancer due to exposure to hexavalent chromium exceeds 1 in 10; this risk is based on occupational standards (Park et al., 2004). Chronic inhalation of chromium in humans results in shortness of breath, coughing, wheezing, bronchitis, decreased pulmonary function, pneumonia, asthma and nasal itching and soreness (Tutu et al., 2008; Das and Singh, 2011; Sluis-Cremer and Du Toit, 1968).

3.5 Health risks of gas and petroleum

Exposure to aerosols from petroleum products used in mining operations poses a health risk, especially for underground mineworkers, where ventilation is a challenge (Bugarski et al., 2014). Diesel particulate matter (DPM) exposure in humans is known to cause cardiovascular dysfunction, eye and nose irritation, headaches, nausea and asthma; it also causes neuro-inflammation and neurodegenerative disease (Levesque et al., 2011; Donogue, 2004, Mauderly, 2001). Elevated and repeated exposure to DPM has also been linked to lung cancer (IARC, 1989; Mauderly, 2001).

4. Documented health risks in ESA countries

Various studies have documented the health risks and outcomes associated with large- and small-scale mining in ESA countries. *Table 3* below summarises the documented health risks in ESA countries and the affected communities,

Table 3: Documented health risks in mining and affected groups in ESA countries

Country	Documented health risks and affected groups
Angola	• Risky sexual behaviour and HIV in migrant mineworkers, communities near diamond mines • Stress in resettled/displaced community members from diamond mining
Botswana	• Sulphur dioxide and particulate pollution causing respiratory disorders in communities living around nickel-copper mines • Silica dust and pneumoconiosis in ex- mineworkers from South African mines
Democratic Republic of Congo	• Silica dust and silicosis in copper and cobalt mineworkers • High concentrations of heavy metals exposing community members and causing various health problems living within 3km of a mine in Katanga province • Environmental and occupational cobalt exposure in artisanal cobalt mining in Kolwezi, leading to DNA damage in children; elevated cobalt urine and blood levels for residents around the mines associated with cardiovascular, respiratory and hematological problems and neonatal malformations due to paternal exposure
Kenya	• Toxic heavy metals from artisanal gold mining activities causing haematological damage, cancer, cardiovascular disease in mineworkers and community members • Stress in resettled/displaced community members from mining
Lesotho	• Migrant workers from South African gold mines with HIV/AIDS, TB/HIV and silico-TB
Mada-gascar	No available literature
Malawi	• Exposure to uranium tailings at a closed mine posing a risk to nearby communities • Silicosis among ex-mineworkers who were formerly employed in South African mines
Mauritius	No available literature
Mozam-bique	• HIV/AIDS, TB/HIV and silico-TB in migrant mineworkers from work in South African mines • Resettlement or displacement leading to loss of livelihood, stress, trauma and waterborne diseases in displaced communities • Mercury poisoning in ASM for gold associated with delayed neonatal development; respiratory and neurological disorders, vomiting, headaches in workers and community
Namibia	• Uranium raising the risk of genetic damage and cancer in miners and ex -miners
Swaziland	• Silicosis in miners /ex-miners from work in South African gold mines • HIV in migrant mineworkers and communities in and moving to and from gold mines • Non-adherence to OSH standards and environmental pollution raising various disease risks among mineworkers and community members living around mining sites
South Africa	• Dust associated with respiratory disease in communities around gold mine tailings • Environmental exposure to uranium and radons increases risk of cancer in the population living in and around gold mine areas and tailing dams • Toxic metals in mining sites and processing plants leading to negative health outcomes among workers, children and community members • Silica dust in copper, platinum, gold mines and in dump sites leading to silicosis, silico-TB, asthma, COPD and TB among mineworkers, ex-miners and community members around mining/dump sites. Respiratory diseases in school children; pre-term births in women; increased hospitalisations and deaths in children and women living around dump sites • Coal dust-related pneumoconiosis in coal miners; cement dust • Asbestosis, lung cancer, mesothelioma, in mineworkers and community members in asbestos, diamond mines. Hypoxia, cyanosis among mineworkers • Cyanide in gold mining linked to haematological damage; neurological disorders, tremors, insomnia, hallucinations, memory loss, cognitive and motor dysfunction in workers and communities. Death post-employment in ex-miners, higher in black miners, gold mines • Mercury in ASGM linked to neurological disorders, tremors, insomnia, hallucinations, memory loss, cognitive and motor dysfunction in workers and communities • Manganese, platinum, chromium inhalation associated with respiratory, reproductive system, skin disorders, hypersensitivity, asthma, allergies, among workers and community

Country	Documented health risks and affected groups
	• Uranium in mine tailings and dumps from gold mines associated with cancer and radioactive toxicity among communities living around mines • Diesel particulate matter linked to cardiovascular dysfunction, ENT irritation, asthma, nausea, neurodegenerative diseases among mineworkers • Limited access to social services in a platinum mine; long working hours and harsh working conditions in gold and platinum mines associated with sexual violence among women and children of migrant workers and stress and poor health among mineworkers • Injuries and death among miners in gold and platinum mines • Stress, poor nutritional status among displaced community members
Tanzania	• Heat exposure and heat-related illnesses in mineworkers in gold mines in Mara • Rock particles and dust at a volcanic block mining site in Kilimanjaro linked to respiratory and ear, nose and throat problems among mineworkers • Respirable dust in an open cast gold mine and NIHL in open pit and underground workers • Noise-related injury and injury and fatalities from falling rock at a Tanzanite mine • Mercury and arsenic in ASM for gold leading to delayed neonatal development; respiratory and neurological disorders, vomiting, headaches among mineworkers and community members; heavy metal poisoning among pregnant women who eat clay • Coal, dust at a coal mines leading to respiratory problems in workers and ex-miners • Low knowledge of OSH in ASM for gold and poor use of protective equipment in Tanzanite mining associated with chemical accidents, injury among miners and community members
Uganda	• Various morbidity in communities near a closed copper mine from heavy metal exposure • Mercury contamination of fish, crops and water from ASM for gold-posing health hazard • Poor PPE practices at mining sites • Marbug hemorrhagic fever among miners due to exposure to bat secretions
Zimbabwe	• Noise at mining sites and noise-induced hearing loss in workers • Lead poisoning in communities living near a closed mine due to lead dust exposure • High concentrations of mercury in water potentially harming communities living around ASGM mines and child labour on the mines; with high urinary mercury concentrations
Zambia	• Rock falls, heavy equipment leading to injury and deaths in underground copper miners • Silicosis/ respiratory disorders in miners, ex-miners, communities from copper mining sites • Sulphur dioxide and particulate matter and heavy metal exposure at copper mines linked to higher toxic metal concentrations in blood, toenails in miners and communities • Lead poisoning in residents and children in close proximity to a closed lead mine in Kabwe • Ergonomic risks for injuries and death in underground mineworkers • Stress from displacement/ resettlement

Sources: Adjemian et al., 2007; Andraos et al., 2018; Baltazar et al., 2015; Banza et al., 2009; 2018; Bloch et al., 2018; Bose-O'Reilly, 2008a; 2008b ;2010; 2017; 2018; Botha et al., 1986; Caravanos et al., 2014; Chadambuka et al., 2013; Charles et al., 2013; Chu et al., 2015; Churchyard et al., 2004; Corbett et al., 2003; 2004; Danjou et al., 2019; EJA, 2019; Ekosse et al., 2004; 2011; Green et al., 2019; Hayumbu et al; 2008; IOM/SIDA, n.d; Kootbodien et al., 2019; Kayembe-Kitenge, 2019; Kesselring, 2018; Kunda et al., 2013; Lim et al., 2011; Mamuya et al., 2018; Mataba et al., 2016; McCulloch, 2003; Meshi et al., 2018; Michelo et al., 2009; Mkandawire, 2015; Mohner et al., 2014; Mshana, 2015; Mtero, 2017; Mulenga et al., 2005; Mwaanga et al., 2019; Mwandira et al., 2018; Mwesigye et al., 2016; Naicker et al., 2003; Naidoo et al., 2005; Ndilila et al., 2014; Nelson et al., 2011; 2013; Ngosa et al., 2016; Nyanza et al., 2017;2019; Omara et al., 2019; Pacyna et al., 2006; Pelders et al., 2019; Phakedi, 2010; Rodrigues, 2017; Rusibamayila et al., 2018; Spiegel et al., 2006; Steele et al., 1997; 2019; Squadrone et al., 2016; Utembe et al., 2015; Wiegnik, 2018; Winde et al., 2019; Yabe et al., 2015; Zaire et al., 1996; 1997

Table 3 shows the mix of physical, biological, chemical, ergonomic and psychosocial risks to health, as well as the impact of accidents and of wider practices such as displacement. The text below elaborates on the evidence.

4.1 Physical health risks

Tanzania has high rates of mine-related injuries. In a study conducted at a tanzanite mine in Tanzania between 2009 and 2012, 248 injuries were recorded with 54% of the miners being younger than 30 years and 98.7% were not using PPE. The leading cause of injury was falling rock (18%) and multiple injuries were recorded in slightly over a third of the miners, 41% of these fatal (Boniface et al., 2013). A retrospective study of injuries and fatalities at a large copper mine in Zambia between 2005 and 2007 found 165 injuries and 20 fatalities. Underground workers were most affected with rock falls, responsible for majority of fatalities and injuries mostly caused by tools (Michelo et al., 2009). In South Africa, mine-related injuries are common in the platinum and gold mines with the risk higher in older mineworkers (Lim et al., 2011). Predictors of ex-miner deaths in South Africa included being black and previous employment in a gold mine (Bloch et al., 2018).

The working environment at a gold mine in Mara, Tanzania, exposed mineworkers to thermal conditions that can contribute to heat illness symptoms (Meshi et al., 2018). A study conducted among volcanic rock miners in Kilimanjaro, Tanzania, found that stone cutting and shaping were associated with respiratory inflammation, cough, and with red eyes in volcanic block mining (Mamuya et al., 2018).

Noise-induced hearing loss (NIHL) has been reported among 47% of mineworkers in Tanzania, more frequent in those with longer exposure, in underground work and in younger mineworkers (Musiba et al., 2015). The prevalence of NIHL in Zimbabwe was found to be 37% among miners; increasing with age and particular work areas (Chadambuka et al., 2013).

4.2 Dust-related health risks

A study among Botswana men formerly employed in mines in South Africa found the prevalence of pneumoconiosis to be around 26.6% to 31% with 6.8% having progressive massive fibrosis (Steen et al., 1997). The authors argued that the high burden of pneumoconiosis in former miners indicated exposure to respirable dust during employment that went undetected due to lack of appropriate services during and after employment. Rusibamayila et al., (2018) investigated respiratory impairment among individuals exposed to respirable dust in underground and open cast gold mines in Tanzania. They found that respirable dust was higher in underground than open pit and the prevalence of respiratory symptoms was higher among underground gold miners, despite their lower threshold exposure to dust. A cross-sectional study of respirable dust at two mines in Zambia showed that 59% and 26% of the samples had crystalline silica content above the US OSHA permissible exposure limit, raising the risk of silicosis, TB and COPD (Hayumbu et al., 2008). A retrospective study in Lubumbashi of 2,500 mineworkers exposed to silica dust at a copper and cobalt mine in 1970-1995 found that 1% of these workers developed silicosis, with a 100% fatality rate in affected workers (Kabamba et al., 2018). The use of PPEs was found to be non-existent. Asbestosis, lung cancer, mesothelioma have been reported in asbestos mining, and while many no longer mine asbestos, also in South African diamond mines (Botha et al., 1986; Nelson et al., 2011).

A study in 2004-2008 with 476 copper mineworkers in Zambia also found a prevalence of silicosis of about 8.8% for an average of 26 years of employment, while a second study found levels of cumulative respirable silica dust to be associated with risk of TB (Sitembo, 2012; Ngosa and Naidoo, 2016). Large-scale gold mines expose miners to respirable crystalline silica in South Africa within the first 5 years of employment if dust control measures are not implemented (Verma et al., 2014, Churchyard et al., 2004; Nelson, 2013; Gottesfeld et al., 2015; Basu et al., 2009, Ehrlich et al., 2018). Silicosis prevalence among black migrant contract workers on a South African goldmine was between 18.3–19.9% (Churchyard et al., 2004). A study of copper mine employee data (n=357) showed a relationship between cumulative respirable silica dust and risk of TB (Ngosa and Naidoo, 2016).

Coal worker pneumoconiosis (CWP) prevalence was estimated at 7.3% among South African coal miners (Naidoo et al., 2005). Silicosis and pulmonary TB was comparable between female and male miners. Poor implementation of dust control measures was a possibility since early onset of symptoms was observed after short-term employment (Ndhlovu et al., 2019). In a study conducted at a coal mine, respiratory symptoms were associated with high cumulative coal dust (Mamuya et al., 2007). Disease–related compensation for miners has paid greater attention to these occupational lung diseases, but also gives an indication of wider occupation-related disease burdens. Of the mineworkers eligible for compensation in South Africa, 28.4% were from Mozambique, Lesotho, Swaziland, Botswana, Malawi and elsewhere in southern Africa, many of which had longstanding morbidity (Kistnasamy et al., 2018).

Respirable silica predisposes miners to TB. There is substantive evidence on silicosis, TB and HIV across most ESA countries, summarised in *Table 4*. The prevalence of silicosis and TB has been shown to vary by exposure duration, population being studied and country as shown in *Table 5* overleaf.

Table 4: Prevalence of mine-related silicosis, TB and HIV in selected ESA countries

Country	Mining in GDP	Number employed in mines	Silicosis in miners/ex-miners	TB in miners/ex-miners	HIV in miners
Angola	0.14%	3,000	-	-	-
Botswana	24.5%	29,043	10.2% miners 26% ex-miners	27% ex-miners	24%
Democratic Rep Congo	22%	120,000	-	-	-
Kenya	0.8%	9,000	-	-	-
Lesotho	7.9%	15,911	25.2% miners 26% ex-miners	30%	14%
Madagascar	4.6%	5,500	-	-	-
Malawi	2.3%	54,000	-	-	4-7%
Mauritius	-	-	-	-	-
Mozambique	3.5%	174,906	-	-	15-42% employed in RSA mines
Namibia	11.5%	19,000	-	-	20-25%
South Africa	5-8%	493,971	27-32%	20% miners	24%
Swaziland	2%	2,520	-	-	20%
Tanzania	3.6%	1,500,000	1.6% mineworkers	-	8.9%; peri-mining,16-18%
Uganda	0.3%	300,000	-	-	-
Zambia	13.4%	68,473	22.7% miners/ ex-miners	65.4% miners/ ex-miners	7-18%
Zimbabwe	10.3%	632,025	0.1% pneumoconiosis		

Sources: Churchyard et al., 2004; EARF, 2018; Loewenson, 2018; Loewenson et al., 2016; Mulenga et al., 2005; TIMS n.d.

One of the bigger studies with a longer observation period and involving 2,114 medical records of copper miners in Zambia between 1945 and 2002 found a prevalence of silicosis of 22.7%, of TB of 65.4% and of silico-TB of 11.9%, with further studies showing an elevated risk of death in workers with silicosis and TB in interactions that are still to be further understood (Mulenga et al., 2005; Utembe et al., 2015; Kootbodien et al., 2019; Balmes, 2017). While evidence of pro- and anti-inflammatory pathway involvement is not consistent, fibro-genesis from silicosis might contribute to a predisposition to TB (Konečný et al., 2019).

Table 5: Prevalence of silicosis and TB by duration of exposure in selected ESA countries

Study population	Silicosis prevalence	TB prevalence	Exposure duration (average)	Country/area
Gold miners	5.7%; 6.2%	-	2.4 years	South Africa
Former gold miners; n=610	24%	30%	25.6 years	Lesotho (work in RSA mines)
Ex-miners; n=228	21%	33%	9.3 years	Eastern Cape, RSA
Ex-miners; n=101	26%	27%	13.4 years	Botswana (worked in RSA mines)
Former white gold miners; n=2235	14%	-	23.5 years	South Africa
Ex-miners; n=271	34%	62%	12.4 years	Transkei (South Africa)
Active black gold miners; n=515	18%	20%	21.8 years	North West (South Africa)
Mine records; n=2114	22.7%	65.4%	1945-2002 (11.9% silico-tuberculosis)	Zambia

Sources: Churchyard et al., 2004; Girdler-Brown et al., 2008; Hnizdo and Sluis-Cremer, 1993; Knight et al., 2015; Meel, 2002; Mulenga et al., 2005; Steen et al., 1997; Trapido et al., 1998.

Significant relationship between mining tenure and emphysema severity has been established in studies done among South African miners between 1975 and 2014; while long-term exposure to inhaled mineral dust led to silicosis, fibrosis, COPD, further research was reported to be needed on the mechanisms for HIV/TB infection and emphysema (Mabila et al., 2020).

There are also risks to surrounding communities. Children attending schools near mine dumps are also at risk of exposure to dusts, with the intensity of asthma attacks and decline in lung function related to exposure levels. Mine dusts are reported to be linked to preterm births and to increased hospital visits and deaths in children with pre-existing asthma conditions or respiratory diseases (Mohner et al., 2014). Indoor respirable dust levels in exposed schools near mine dumps were found to be above acceptable limits (Nkosi et al., 2017).

4.3 Chemical health risks

Mining in the region is associated with various chemical hazards, with mining and mine dumps contaminating the environment with metals, acids and toxic waste, found to be above permissible limits in selected southern African studies (Coetzee et al., 2002; Durand, 2012; McCulloch, 2003).

Sulphur dioxide and particulate air pollution were reported to be prevalent at a nickel-copper plant in Botswana with residents close to the mines and smelter plants at greater risk of exposure (Ekosse, 2004; 2011). Copper mining is associated with exposure to silicates during extraction and sulphur dioxide fumes during smelting (Mwaanga et al., 2019). Residents of Selebi-Phikwe, a nickel and copper mine, reported frequent coughing, headaches, influenza and colds and chest pains from environmental hazards from mining and mineral processing activities, with those living in sites closest to the mine and smelter/concentrator plant reporting a higher incidence of these symptoms (Ekosse, 2005). In Zambia copper mines, sulphur dioxide and particulate matter (fine and ultrafine) are reported to be released into the environment from smelters, while particles from waste rocks and tailings/dump sites are associated with silicosis and TB (Mulenga et al., 2005). In certain townships, the emissions from smelters were found to exceed the limits prescribed in national and international standards.

Toxic metals can contaminate soils, water and food, during mining and after mine closure. In Katanga Province, DRC, a biomonitoring study of 351 community members found urinary concentrations of heavy metals and other trace elements to be significantly higher in people living within 3km of mining sites than those living 3-10km away, with 53% of all study participants and 87% of children affected. Cadmium, copper, lead and uranium levels were found to be the highest ever reported in a general population globally (Banza et al., 2009). Some of the world's richest cobalt reserves are in Katanga Province, DRC; the metal is used in the production of various electric and communication technologies (Milesi et al., 2006). Artisanal cobalt mining/extraction in Kolwezi, DRC, and poor management of mining wastes were found to lead to elevated concentrations of cobalt in urine and blood, higher in children and those living within the sites of cobalt extraction and with evidence of exposure-related genetic damage in children (Banza et al., 2018). Lake Tshangalele in Katanga province, DRC, is highly contaminated with heavy metals from mine effluents, with fish samples from the lake found to contain heavy metals in higher concentrations than permissible levels, exposing those consuming fish from the lake, and with harm to babies in utero in mechanisms that are not yet well understood (Squadrone et al., 2016; (Kayembe-Kitenge et al., 2019; Chenys et al., 2014; Smolders et al., 2019; Amadi et al., 2017).

In Kenya, mining activities have been found to contaminate agricultural soils with manganese and iron, which later find their way into crops consumed by humans (Maina et al., 2016). Gold ores from AGM activities in Nyanza, Kenya, contain arsenic, lead, titanium and zinc, with soil contamination at concentrations well above WHO recommended levels, exposing workers and communities. Together with exposure from mine wastes, those exposed are reported to have experienced harm to brain development in children, dementia in adults, poor birth outcomes in pregnant women, liver damage, kidney disease, emotional instability and vision impairment (Odumo et al., 2011; Amadi et al., 2017; Jan et al., 2015).

The region is affected by mercury contamination from gold mines with people working or living in or near these mines found to have high urinary concentrations of mercury (van Straaten, 2000; Engström et al., 2013; Bose-O'Reilly et al., 2008a). ASM has been associated with risks of exposure to chemical hazards, noise, dust, psychosocial risks and violence, without control measures on mines and with weak legal or institutional protection (TIMS n.d; Nyanza et al., 2017; Noetstaller et al., 2004; ILO, 1999). Mercury used for gold extraction is easily acquired from private suppliers making its use difficult to regulate. Community members engaged in artisanal small-scale mines have limited knowledge of the health risks associated with arsenic and mercury in the process of gold mining (Charles et al., 2013). Exposure to mercury causes neurological and behavioural disorders tremors, insomnia, hallucinations, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunction (Langford and Ferner, 1999). There is, however, limited reliable data on exposed persons and on the factors affecting people's uptake and elimination of mercury (Engström et al., 2013).

ASM gold miners in Tanzania exposed to mercury were found to have neurological disorders and body levels of mercury above permissible limits, with report of negative birth outcomes and delayed development, especially in amalgam (mercury-gold alloy) burners (Nyanza et al., 2019; Bose-O'Reilly et al., 2017). South African mining is for example ranked second among the countries emitting mercury into the environment (Pacyna et al., 2006). Zimbabwe is also reported to be using large quantities of mercury in gold mining, and children involved in small-scale gold mining in the country were found to have higher mercury concentrations in their blood, urine and hair than the recommended levels, and women workers in ASM gold mines pass it to babies through breast milk (Steckling et al., 2014; Bose-O'Reilly et al., 2008a). Chronic mercury intoxication is argued to have been one of the top 20 hazards to population health in Zimbabwe in 2004 (Steckling et al., 2014). High levels of mercury exposure among residents near South African mines has been reported, with approximately 50% exposed (Oostheuizen et al., 2010). In Munhena, Mozambique, about 12 000 ASM gold miners were reported to be at risk exposure to mercury, with further exposure in their families (Spiegel et al., 2006). Minimal environmental monitoring and lack of mine waste management was also noted in gold mines in Tanzania.

Exposure to cyanide used during gold extraction can lead to hypoxia and cyanosis because cyanide prevents cells from utilising oxygen, leading to convulsions, loss of consciousness and suffocation (Naicker et al., 2003; Logsdon et al., 1999). In South Africa, for example, the waste from gold cyanidation (extracting gold by first dissolving ores in alkaline solution and then separating gold solution from the solids) is dumped in tailing dams which then leaches and contaminates the environment, exposing communities living near the gold mines (Phakedi, 2010; Logsdon et al., 1999). Communities are not aware of these risks and small-scale gold miners in Tanzania were found to have limited knowledge of the Cyanide Code (Nyanza et al., 2017).

Platinum sensitivity has been detected among platinum refinery workers in South Africa (Calverley and Murray, 2005). Environmental exposure to platinum has also been detected among non-mineworkers (Wiseman and Zereini, 2009). In Namibia, miners exposed to uranium have a higher risk of genetic damage (Zaire et al., 1996; 1997).

Mining tailings and dumps have been found to contain elevated levels of uranium (Winde et al., 2004a). Gold mining in South Africa has been found to lead to uranium contamination in Gauteng province with high levels observed in areas near gold-mine tailings (Danjou et al., 2019; Kamunda et al., 2016b; Winde et al., 2004a). These contaminants find their way into the human body through inhalation from polluted air, skin absorption, consumption of crops grown on contaminated soils or drinking water from contaminated surface or ground water or consumption of fish from contaminated rivers (Ngole-Jeme and Fantke, 2017; Winde and Sandham, 2004). Sediment and tailing samples collected from ASM gold mines in Zimbabwe in 2015 found mercury contamination of local streams (Green et al., 2019). Analysis of soil samples from mine tailings and villages in South Africa found arsenic, chromium and nickel in higher than accepted levels posing health risks to adults and children, while uranium has also been found to leach into ground and surface water, exposing communities near gold mine tailings to radioactive materials (Kamunda et al., 2016a; Winde et al., 2004a; 2004b; Winde and Sandham, 2004). Hair sampled from barbershops in gold mine areas in Gauteng province, showed higher levels of exposure to uranium, raising the risk of cancer (Winde et al., 2019).

Mine effluents can contaminate soil, water bodies and fish (von der Heyden and New, 2004; Kamunda et al., 2016a). In Tanzanian ASM gold mines this was found to lead to arsenic, copper and manganese exposure in fishermen, water, soil and cassava in nearby villages, as well as pregnant women practising pica (clay eating) (Nyanza et al., 2014a; 2014b; Mataba et al., 2016). In Kabwe, Zambia, mine dumps were reported to be a source of lead contamination, exposing communities living near the former lead mine and smelter, with 95% of children in the area having elevated blood lead levels (Mwaanga et al., 2019; Bose-O'Reilly, et al., 2018; Yabe et al., 2015; Caravanos et al., 2014). People living near and around copper mines in Zambia were found to have higher concentrations of cobalt, copper, lead, selenium, zinc metals in their toenails than those from non-mining areas (Ndilila et al., 2014).

The evidence shows that tailings and dumps post mining thus present a potential risk of exposure to toxic substances after mine closures for communities living near mine sites (Utembe et al., 2015; Lottermoser, 2010). In Uganda, soil, water and crops near tailings from an abandoned copper mine were found to be contaminated with copper, lead and zinc at higher than the recommended thresholds, with yams, fish and other crops in nearby communities showing signs of exposure, albeit within permissible limits (Mwesigye et al., 2016; Omara et al., 2019). Lead contamination from post closure dump sites in Kabwe, Zambia, have been reported to be responsible for ongoing lead poisoning to people living nearby, including through wider ground water contamination due to leaching (Mwandira et al., 2018). Tailings from a closed uranium mine in Malawi were reported to raise concern over potential health risks to communities living nearby (Mkandawire, 2015).

4.4 Infectious disease health risks

Risky sexual behaviours associated with migratory work, oscillatory home-mining movements and social exclusion are reported to raise the risk of HIV in mining communities (IOM, n.d.; Martins-Fonteyn et al., 2017). In Angola, migrant mineworkers are likely to live in single quarters unaccompanied by their spouses, a situation that predisposes them to risky sexual behaviour due to social exclusion, boredom and limited home leave (IOM, n.d.). In a 2004, about 27% of gold miners in South Africa were said to have HIV, including migrant workers from Lesotho, Mozambique, Swaziland, and Botswana (Corbett et al., 2004). Mozambican workers working in South Africa mines were, for example, found to have HIV prevalence rates of 22.3 %, with 74.6 % of those testing positive not knowing their status (Baltazar et al., 2015). Their risk of TB/HIV coinfection is also high, as is their risk of silico-TB. This co-morbidity with TB was discussed earlier in *Section 4.2* and not repeated here, but is highly relevant to the spread and control of TB in the region.

Mineworkers are also exposed to other infections as was noted in Uganda, where a Marburg hemorrhagic fever outbreak was detected in a mine in Ibanda district, due to miners not using PPEs and thus exposed to bat secretions (Adjemian et al., 2007). Poor living conditions in unplanned settlements, whether due to an influx of populations in mining areas or due to displacement, can lead to an increased risk of cholera and other infectious diseases outbreaks, as was the case, for example, in Tete province, Mozambique (Loewenson and Simpson, 2015).

4.5 Ergonomic, psychosocial and socio-economic-related risks

Mineworkers suffer from fatigue due to long working hours/shifts, heavy loads, harsh working and living conditions predisposing workers to higher stress and more sick leave (due to frequent poor health) and lower job satisfaction (Pelders and Nelson, 2019). A retrospective study of the occurrence of injuries and fatalities at a large copper mine in Zambia between 2005 and mid-2007 found 165 and 20 injuries and fatalities respectively, mostly due to rock falls and tools (Michelo et al., 2009). In Zambia, the prevalence of work-related musco-skeletal injuries in a survey of 202 underground mineworkers was 42.6%, primarily due to poor posture and lifting of heavy weights, affecting mainly the back and those working as mechanics (Kunda et al., 2013).

Mining communities also experience psychosocial problems. The risks of migratory work and poor living conditions were noted earlier to be associated with a higher risk of unsafe sexual practices and HIV, and high levels of sexual violence have been reported affecting women and children in a migrant labour community on a platinum mine in South Africa, an area, with limited access to protection, health and social services (Steele et al., 2019).

Mining developments have, as noted earlier, led to displacement and resettlement of community members living near mining sites, generating the stress, tension and conflict noted earlier when resettlement is poorly planned without consulting communities, especially in the context of the power imbalances between poor communities and mine investors noted earlier (Rodrigues, 2017; EJA, 2019; Wiegnik, 2018). Evidence from rural South Africa revealed how displacement has the potential to reduce farm outputs and push communities further into poverty, with negative consequences for nutrition and mental stress in affected communities (Mtero, 2017).

5. How far do documented risks in ESA match current knowledge?

These documented health outcomes in ESA countries show that there is evidence, much of it from ad hoc surveys, on a range of health outcomes from large- and small-scale mining activities. Nevertheless, there are also gaps between what is documented in the region and what is known from wider international studies and knowledge on the different types of mining in the region. *Table 6* summarises the information from the current knowledge presented in *Section 3* with what is documented in the region, presented in *Section 4.*

Table 6: Summary of review findings for risks, outcomes and gaps by type of mining

Types of mining, known risks and health outcomes	Gaps between known outcomes and those documented in the region
Gold:	
Silica dust o Silicosis in miners and ex-miners o TB in miners, ex-miners, community members and their contacts Asbestos- Asbestosis among workers	Silicosis, TB monitored in workers and levels documented. Limited information on environmental exposure for communities and ex mineworkers under-reported. Limited understanding of mechanisms for TB - silica interactions
Mercury vapor, cyanide, arsenic and heavy metal exposure for miners and communities o COPD, hypoxia, cyanosis, cancers in miners o Harms to neonatal and child development	The extent of mercury exposure and long term health outcomes unreported in some countries and especially for ASMs
Environmental exposure of community members to toxins from tailings and dumps - respiratory diseases such as asthma, emphysema, coughs in children	Ad hoc survey reporting of cancers among workers, children and women; no evidence on genetic risks and developmental outcomes
Heat exposure- heat exhaustion, burns, fainting	Not well document in most ESA countries
Poor living and social environments and behaviours o HIV and other STIs for miners and their partners o Alcohol and other substance abuse	Evidence on HIV; Less evidence on other risks and outcomes for communities near mining sites and along transport corridors.
Copper:	
• Exposure to dust and silica dust o Silicosis, pneumoconiosis, COPD in miners and ex-miners o TB in miners, ex-miners, community members and their contacts	• Silicosis widely studied in miners; limited evidence on COPD; on the level of TB co-infection in communities. Limited surveillance or on environmental exposure monitoring of communities living near mines
• Exposure to sulphuric acid fumes for miners and community members - respiratory diseases, asthma, emphysema, coughs, in school children, miners and community members	• Ad hoc surveys of neurological disorders among community members
• Exposure to heavy metals and iron ores- harming brain development in children, mental disorders, dementia in adults, poor birth outcomes, liver damage, kidney disease, vision impairment.	• Ad hoc surveys on blood cancers, lung cancer in workers, ex mineworkers and community members. No evidence on foetal exposure, maternal health outcomes.
Coal:	
Exposure to coal and other dust – pneumoconiosis, emphysema, silicosis, cardiovascular disease for miners and communities	Limited reporting of asthma, emphysema and respiratory disease in miners and communities near coal mines, or of associated fatality.
Heat exposure – burns, heat exhaustion, fainting and stroke in miners	No documentation of heat related morbidity
Exposure to gases – respiratory illnesses for mine workers	
Exposure to contaminated water and soils – cancer, delayed development in children, dementia in adults, still births/miscarriage in pregnant women, liver damage, kidney disease, emotional instability and vision impairment for nearby communities	Ad hoc reporting of lung cancer in mineworkers, ex-miners and community; negative birth outcomes in the surrounding community. No reporting of associated fatality levels.

Types of mining, known risks and health outcomes	Gaps between known outcomes and those documented in the region
Uranium: Exposure to radioactive materials and contaminated air, soils, food and water in nearby communities o Lung cancers among miners, ex-miners and community members o Risk of premature death for irreversible outcomes o Neurotoxicity and genetic damage for exposed children including risk of cancer in adult life	Some information on exposure and blood cancers (leukemia, myeloma, lymphomas) but the burden of cancers, genetic harm attributable to mining for workers, resident communities is not documented.
Platinum: Exposure to dust particulate matter and heavy metals- Cutaneous eruptions, severe asthma, severe skeletal deformities and cancer among miners, ex-miners and community members	The burden of cancer and other platinum-related morbidity in miners and communities is not documented in ESA countries
Chrome: Exposure to chromium - shortness of breath, coughing, wheezing, bronchitis, decreased pulmonary function, pneumonia, asthma and nasal itching, soreness and cancer among miners, ex-miners and community members	Evidence gap on cancer risks and outcomes No documentation of exposure to heavy metals for community members living near chrome mines
Manganese: Exposure to manganese- bronchial and lung disease, impotence and neurological damage for mine workers and exposed community members.	No evidence on health outcomes of exposure to manganese for workers and communities
Cobalt: Exposure to cobalt – heart, lungs, blood and thyroid diseases, cancer in workers and community members Environmental contamination with heavy metals – cancers, Respiratory diseases (asthma, pneumonia, hard metal lung disease in community members	Limited information on health outcomes of cobalt exposure in the region Limited information on the health outcomes and of heavy metals in blood and urine of community members
Diamond: Exposure to asbestos - asbestosis, mesothelioma among miners and ex-miners Crime and violence – injury, trauma, death for communities near mining sites	No information on ex-miner and community health outcomes, asbestosis and cancer Limited documentation of crime and violence related to diamond mining
Petroleum/gas mining Diesel particulates– Cardiovascular dysfunction, eye and nose irritation, headaches, nausea and asthma, it also causes neuro inflammation, neurodegenerative disease, lung cancer, respiratory disorders in mine workers Heat, fire –Burns, heat exhaustion, fainting and death among workers	Limited evidence on health outcomes associated with diesel particulates in miners and mining communities Cardiovascular dysfunction reported in workers Adhoc reporting of heat exposure and fire incidents among ESA mines

NB: *Noise leading to NIHL in miners and accidents leading to injury and death for miners are found in all types of mining in the literature. In ESA countries, while accident related injury is recorded in large mines, there is less evidence in ASMs and limited information on NIHL in all mines. More information is available from gold, coal and copper mines than from other types of mining in the ESA region.*

Sources: Basu et al., 2015; Banza et al., 2009; Blackley et al., 2018; Bose-O'Reilly et al., 2008a,b; Bugarski et al., 2014; Churchyard et al., 2004; Ehrlich et al., 2018; Gottesfeld, et al., 2015; 2018; Haney et al., 2012; Levesque et al., 2011; Loewenson et al., 2016; Nkosi et al., 2017; Pelders and Nelson, 2019; Sitembo, 2012; Steele et al., 2019; Mwaanga et al., 2019; Nelson et al., 2011; Proctor et al., 2016; Yabe et al., 2015.

The findings as summarised in *Table 6* suggest that routine surveillance and compensation systems generally track silicosis, accidents and injury in formal sector workers in ESA countries, but less so in workers in ASM, despite their risk, and with under-reporting in ex-mineworkers. Increasing attention has been paid to HIV and TB in recent years across most ESA countries, and there is evidence on the interaction between silicosis, TB and HIV in the region. Yet it is unclear how far these co-morbidities are affecting those surrounding communities.

For other risks and conditions, what has been documented in international literature is not as well captured through surveillance and is documented through ad hoc surveys. Research has been conducted on physical, chemical and biological hazards related to mining, more so than on ergonomic and psychosocial hazards, including sexual violence, crime, alcohol and harmful drug use. However, the surveys are focused more in specific ESA countries, particularly South Africa, Zambia, Zimbabwe and Tanzania. In other ESA countries - Uganda, Mozambique, DRC and Botswana – there are fewer studies on isolated risks, and even more limited information was found on risks and their health impacts in Angola, Malawi and Namibia. There is evidence of long-term, chronic disease risks in wider literature, including cancers, brain and nervous system development, and in negative reproductive, pregnancy outcomes and genetic outcomes in exposed communities. Yet this is the area that is least well assessed in the region, especially for women and children and those in ASM. There is evidence of widespread use of toxic chemicals such as mercury and arsenic in mining, yet little monitoring of the chronic morbidity that is known to be associated with these chemicals in the ESA region. There is evidence that mine tailings and dumps are associated with lead, uranium and other forms of exposure to nearly communities, but the systems for screening workers do not continue after mines close, under-reporting this morbidity. There is survey evidence of contamination of water, soils and foods – crops and fish- that can expose all age groups and particularly children. However, these risks are not necessarily prevented through planning for them health impact assessments, monitored or managed.

The evidence in *Table 6* suggests a range of gaps between what has been scientifically documented as health risks and outcomes of mining, and what has been documented in the ESA region. The evidence suggests that these areas are still poorly monitored and that communities and particularly small-scale mineworkers are themselves not informed of these risks.

6. Discussion

Mining has been widespready in the ESA region and both large- and small-scale mining operations have expanded given their economic importance for most ESA countries. This paper has presented the range of health risks associated with mining in the ESA region, including: heat, noise, dust, silica, asbestos, coal, heavy metals, radioactive materials, chemical hazards and accidents. These hazards are associated with a range of direct health outcomes, including silicosis, pneumoconiosis, TB, emphysema, NIHL, cancers, injury and death. The exposure pathways vary by type of mineral and mining process and include ingestion, inhalation, skin absorption, consumption of food or fish affected by polluted water or soils.

The risks not only directly affect workers during employment, they affect workers after employment, communities and even foetuses in utero. Communities living near mines are affected by the environmental consequences of mining, including the loss of biodiversity and exposure to contaminants in air, water, soil and foods. Women and children are affected. Communities may be exposed directly to contaminants from mine processes, but also to wider effects, such as: unplanned population movements into mining areas, increasing the risk of infectious diseases such as cholera, sexually transmitted diseases and viral haemorrhagic fevers; displacement of local communities affecting incomes and living conditions with harm to nutrition and health, or social exclusion of migrant workers far from home raising the risk of social ills such as alcohol and drug abuse, risky sexual behaviours and violence. The migratory nature and insecurity of employment of mining in the region is associated with a risk of communicable diseases, that could be spread within countries and across borders, but also of ex-mineworkers returning to home communities with chronic conditions, including but not limited to the silicosis that has had some recognition, without adequate detection, monitoring or management of these conditions.

These public health challenges call for a multisector, multistakeholder, multidisciplinary and regional response that also engages the international nature of corporate mining. While the primary burden is on the affected miners, ex-miners and communities, there is a wider and accumulating burden in the spillover of unmanaged conditions to families, communities, across generations and to services and social security. While there is growing, albeit still some level of under-reporting of silicosis, TB and HIV individually and as co-morbidities in the region, particularly in recent years, and while compensation systems cover accidents and injury, especially in formal sector workers, the evidence in the paper suggests a systematic under-reporting of the range of other health impacts of mining in ESA countries, This suggests a significant level of externalising of the health burdens of mining to workers and communities, who are already struggling with social and economic insecurity.

This is particularly the case for small-scale mining and ASM. Despite its expansion, with operations now covered by law in some countries, it remains relatively unregulated and marginalised from services, and those involved have limited knowledge of the hazards or control measures. Yet there is evidence of exposure of chemical hazards, such as mercury, affecting all age groups, including fetuses in utero and in child workers on small-scale mining, suggesting a need to end use of mercury and child labour in ASM.

Studies in the ESA region point out that the health consequences identified in the international literature of the types of mining in the region do indeed occur in the region. The studies are, however, ad hoc and focused on a few countries. They indicate that there are gaps in more systematic monitoring and the public reporting of the wider range of conditions arising from mining activities, such as cancers, neurological, reproductive and genetic disorders, particularly for women, children in mine communities and in ex-miners and communities post closure. Health problems were sometimes found even where exposure was within documented permissible exposure limits, suggesting need for local studies to effectively assess and update these limits. Although there is better evidence on silica exposure and TB outcomes, even here there is still limited understanding of the pathways involved in the mechanisms of reaction to the combination of silica and MTB, or of how HIV/TB infection leads to emphysema in miners.

While some countries such as South Africa have multiple studies, others such as Malawi and Botswana have limited studies on mining and public health, suggesting a need for a more equitable distribution of research resources, but also of a need for more systematic monitoring. Of note, many of the studies are not up to date, there are variations in the methods used making it difficult to make comparisons and more well-established formal mining processes are more studied than others, such as ASM mining or mining of platinum, chrome, manganese and cobalt, notwithstanding their economic importance. These information gaps make it difficult to understand the health burden of mining in the region, to develop actionable recommendations and exposure limits for the different types of mining, affected populations and context, or to apply appropriate safeguards.

The economic burdens of these health impacts fall on the affected people, their families and communities, as well as on the enterprises and national economies. As far as direct compensation is concerned, there is concern over delays in compensation funds reaching eligible beneficiaries. Of
The current estimate of 2 million ex-miners in southern Africa, 200,000 are eligible for compensation from the Compensation Commission for Occupational Diseases and 700,000 from the Medical Bureau of Occupational Diseases (World Bank, 2015). However the compensation criteria need to be updated to address the full spectrum of risks and morbidities associated with mining, and many workers, particularly migrant workers returning to home countries, will not have access to the

screening to determine the occupational nature of their illnesses, and local health workers may also not be aware of these occupational determinants. The economic burdens are also externalised for communities displaced by mining, where the evidence suggests that their weaker negotiating power and sometimes weaker legal protection mean that resettlement plans do not adequately cater for their needs and increase their social and economic insecurity. For children affected by lead and other mine-related harms to their neurological development, the burden extends to their future development and thus their socio-economic wellbeing.

7. Conclusions and recommendations

It is acknowledged that there are no quick solutions to these challenges. Nevertheless, the gaps between known risks and what is reported in the region could be addressed through tangible steps. There are well-documented measures for assessment and management of workplace risks and for control measures at source and through personal protective equipment. There are legal provisions that set workplace standards and these need to be updated and implemented, together with revision of permissible exposure limits and the implementation of medical surveillance of workers for the wider range of known risks of particular types of mining. This needs to include provisions for the registration and ongoing surveillance of ex-miners, including through post-employment surveillance. This includes surveillance of infectious disease risks as public health issues to protect individuals and prevent transmission to wider communities. There is need for updated studies on the range of health conditions of ex-miners, beyond silicosis alone, to inform responses and allocation of resources.

Many of the health risks found, however, affect wider communities in non-occupational exposures, through environmental contamination by mining operations and sometimes through the interaction of between community members with miners or ex-miners. There are no regional standards for non-occupational exposure limits and these health outcomes are poorly monitored, except in ad hoc surveys. Rigorous health impact assessments could however be undertaken prior to licensing of new mining developments to assess and prevent these wider health burdens. Many ESA countries have gaps in understanding the conditions of affected populations post-displacement to inform policy dialogue on measures to avoid negative health impacts of displacements, including malnutrition and loss of access to healthcare and other social services.

There gaps between the documented risks and health outcomes associated with mining in scientific literature and what has been documented in the region. This calls for improved monitoring and information systems and wider research practice across all countries of the region, especially as large and small scale mining operations expand. The public health consequences require updated, quality information to support development of comprehensive public health policies and interventions, based on a more accurate understanding of the health burdens and risk factors in all countries of the region. The recommendations below suggest various areas for future attention to enable this:

a. *Improved legislation, regulation and policy* for governments to integrate environmental and health consequences into decisions on mining licensing, with a duty for pre-licensing health impact assessments to set plans to address the spectrum of health risks for mineworkers and their families, ex-mineworkers, surrounding and displaced communities, for post closure duties as well as for the ASM. The processes should involve affected communities and monitor implementation of plans, balancing economic and health benefits and consequences and prioritising public health. Laws should update exposure limits, taking international evidence and local studies into account, and include exposure limits also for affected communities. Regulatory agencies need to improve their capacities for law enforcement, including ensuring an end to child labour with hazardous substances such as mercury. At the same time an amnesty for undocumented ex-miners may assist to encourage uptake of health screening and services and prevent community transmission of communicable diseases, while also ensuring improved conditions for migrant mineworkers in line with the provisions of the International Convention on Protection of Migrant Workers.

b. *Surveillance and research:* ESA countries should improve surveillance systems for key health outcomes associated with mining for miners, ex-miners and communities and document and share best practices on this. Countries should consider introducing biomonitoring of heavy metals in antenatal and post-natal care for women employed in mining or living close to mines or mine tailings to avoid neonatal harm. People living in in close proximity to mining sites should have regular medical checks linked to the known risks. The surveys in selected countries need to expand to underserved countries, and further work be done to investigate pathways exposing communities to heavy metals and other contaminants to quantify health outcomes and identify prevention methods, including where this relates to food chains.

c. *Risk reduction:* Investments need to be made in effective and appropriate management of identified risks. This includes identifying and managing risks at the source, along the path, through personal protective equipment; through management of mine wastes and through widespread information and education to workers and affected communities. Miners need to be well informed on key health issues as they are first responders and can link with community members to support their health literacy on the issues arising from wider environmental contamination from mines. Where communities live in contaminated areas, mitigation measures need to be put in place, or if not possible, communities resettled in improved environments. This applies also to schools in close proximity to mines and mining dumps, together with remediation measures to safeguard the health of children. Lead remediation, radiation protection and ongoing monitoring and surveillance are key to detect, prevent and avert negative consequences and need to be more systematically implemented. Affected workers and communities should be involved in raising evidence on their conditions, and in the decisions on and design of plans and programmes, with support from unions and civil society. While health impact assessments should identify risk-reduction measures before licensing, after licensing, the implementation of these plans need to be monitored, with milestones and indicators to close the gap between commitments and reality, with penalties for breaches, including for mine owners who exceed stipulated allowable occupational and environmental emissions.

d. *Technology development:* The hazard control, medical surveillance, waste management, remediation and related interventions call for technology development and multisectoral, multidisciplinary co-operation. ESA countries should invest in innovating safer mine processes to minimize risk in large- and small-scale mining. For example, research can explore ways of extracting gold without use of mercury amalgamation, or engineering and mechanical controls to limit mineral dust exposures in workplaces and communities.

e. *Detection and management of occupational health-related diseases:* ESA countries need to invest in appropriate diagnostic capacities through regional and national training, to screen for and detect diseases early, to understand health burdens in miners, ex-miners and communities and to manage these burdens at individual and population levels. This calls for improved access to healthcare for all of these groups, including expanding the one-stop occupational health centres in the region. Beyond short- and long-term training programmes, ESA countries could also improve the infrastructure for surveillance and set up regional networks for cross-country collaboration and information sharing, including better management of cross-border surveillance of ex-mineworkers' health and of health risks along transport corridors for mine products, and to share information on risks from multinationals operating in multiple ESA countries.

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Acronyms

ASGM	Artisanal Small-Scale Gold Mine
ASM	Artisanal Small-Scale Mine
COPD	Chronic Obstructive Pulmonary Disease
CSR	Corporate Social Responsibility
DPM	Diesel Particulate Matter
DRC	Democratic Republic of Congo
ELAW	Environmental Law Alliance Worldwide
ESA	East and Southern Africa
HBCs	High Burden Countries
ILO	International Labour Organisation
IOM	International Organisation of Migration
MOH	Ministry of Health
NIHL	Noise Induced Hearing Loss
OEL	Occupational Exposure Limit
OSH	Occupational Safety and Health
PEL	Permissible exposure limit
PPE	Personal Protective Equipment
REL	Relative Exposure Limit
SADC	Southern Africa Development Community
STDs	Sexually Transmitted Diseases
TB	Tuberculosis
TEBA	The Employment Bureau of Africa
TIMS	TB in the Mining Sector
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
WHO	World Health Organization