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28th Collegium Ramazzini Statement
Reducing disease and death from artisanal small-scale mining (ASM)

Collegium Ramazzini

The Collegium Ramazzini is an international scientific society that examines critical issues in occupational and environmental medicine with a view towards action to prevent disease and promote health. The Collegium derives its name from Bernardino Ramazzini, the father of occupational medicine, a professor of medicine of the Universities of Modena and Padua in the late 1600s and the early 1700s. The Collegium is comprised of 180 physicians and scientists from 35 countries, each of whom is elected to membership. The Collegium is independent of commercial interests.

The urgent need for responsible mining in the context of growing global demand for minerals and metals for climate change mitigation Artisanal Small-Scale Mining (ASM) is one of the world's most dangerous occupations. The World Bank estimates that 100 million children, women and men work in ASM worldwide, mostly in remote rural areas of Low-income and Lower-middle-income countries. These miners often work under extreme conditions, the communities where they and their families live are heavily polluted, and ASM is responsible for high, but preventable rates of disease, injury, and premature death.

ASM is increasing rapidly. Paradoxically, a key driver of this growth is climate change mitigation.

Climate change mitigation drives ASM because ASM is a major source of minerals and metals such as lithium, cobalt, nickel, manganese, platinum, cadmium, molybdenum, neodymium, and indium that are critical for the production of solar cells, wind turbines, high-efficiency storage batteries, and electric vehicles that are essential for the transition to a low-carbon economy. The World Bank projects that renewable energy systems will require significantly more minerals and metals than current fossil-fuel-based energy supply systems and that global demand for minerals and metals will continue to increase for many decades.

The goals of this statement, which the Collegium Ramazzini issues during the United Nations COP 26 meeting on Climate Change are to:

- **Provide updated information on the neglected health hazards of ASM and on strategies for mitigation of these hazards in the context of rapidly growing global demand for minerals and metals to meet the urgent need for climate change mitigation;**
- **Raise awareness of ASM hazards among policy-makers and the public;** ***and***
- **Call for urgent interventions against the grave dangers of ASM by international organizations, governments, employers, and minerals and metals purchasers.**

The Collegium Ramazzini notes the gross injustice of ASM. While most ASM takes place in the Global South, in the same countries already suffering the most serious consequences of climate change, most who benefit from ASM are in the Global North and thus have a shared responsibility to encourage their governments to contribute to reducing ASM hazards.

We cannot achieve climate change mitigation through the use of "blood minerals".

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Artisanal and Small-Scale Mining (ASM) is highly dangerous work associated with multiple occupational and environmental hazards. In most mines little consideration is given to health and safety. Governmental oversight is rare, especially in areas where ASM is illegal. Severe injuries such as falls from heights, crush injuries from cave-ins, and lacerations and amputations from unguarded machinery are common. Because there is little separation between working and living areas in ASM, miners, their families, and residents in mining communities are at risk of exposure to hazards associated with mining for 24 hours each day, every day, throughout the year, often under very primitive conditions.

Artisanal and small-scale miners are exposed in their work to multiple toxic hazards, most notably mercury, lead, cyanide, arsenic, cadmium, and cobalt:

- Mercury exposure occurs mainly in gold mining, where milled ore is mixed with mercury to form an amalgam, and the amalgam is then vaporized to produce highly toxic mercury vapor. Mercury exposure occurs also in mercury mining. Extensive exposure to both metallic and organic mercury occurs in ASM. Along with coal combustion, ASM is one of the world's two largest sources of mercury pollution.
- Cyanide exposure is another very serious hazard of gold mining and occurs when cyanide is used as an alternative to mercury in the separation of gold from ore.
- Lead, arsenic, and cadmium exposure occurs in mines where lead, arsenic, cadmium, gold and other metals occur together in the mineral ore.
- Cobalt exposure occurs in cobalt mining.
- All those exposures have multiple adverse health outcomes, including serious social implications.

Artisanal and small-scale miners are occupationally exposed to physical hazards, most notably airborne dust and noise:

- Levels of silica-laden dust tend to be especially high in hard rock ASM mines, and silica exposure increases risk of death from respiratory diseases including silicosis, tuberculosis, lung cancer, and COVID-19.
- Noise levels in artisanal and small-scale mines are typically far above acceptable levels due to the poorly regulated use of dynamite and heavy machinery. Sustained noise exposure can lead to hearing loss, cognitive and behavioral disabilities.

Artisanal and small-scale miners are at high risk of infectious diseases:

- The COVID-19 pandemic affects disproportionately ASM miners and their communities because hand washing facilities, face masks and provisions for physical distancing are rarely available.
- Silica exposure, which is widespread in ASM, weakens the immune response thus increasing vulnerability to tuberculosis and COVID-19 infection.
- Rates of enteric diseases are high due to frequent lack of hygiene and sanitation facilities in the mines and insuf-

ficient access to clean water and food.

- Sexually transmitted diseases including HIV/Aids are common among mobile men with money (MMM), including miners.

Women and children in ASM and in ASM communities face unique and severe risks. Women of childbearing age and young children are highly vulnerable to mercury toxicity, lead poisoning and other hazardous chemical exposures. Women may be subject to sexual assault, violence, and psychological abuse, and they often face discriminatory work practices. Child workers are at risk of exploitation, physical and psychological abuses, and are subjected to working conditions where physical strain and chemical exposures may result in permanent lifelong disabilities.

Artisanal and small-scale miners' health and the health of their families are further eroded by corruption, malnutrition, violence, lack of access to health care and lack of education. Poverty is the main driving force for ASM, and its impacts are worsened by a lack of adequate and collaborative formalization efforts in the ASM sector.

Demand for metals. Strong and rising global demand for metals is the major driver of increases in ASM, and mineral demand is expected to continue to increase by as much as 450% by 2050. Climate change is a critical factor in this increased demand, because vast quantities of key minerals are needed for low- carbon energy technologies such as solar and wind power, e-vehicles, and new-generation batteries. The impacts of this increased demand are expected to be massive in countries such as the Democratic Republic of Congo, which holds roughly half of the world's cobalt reserves (Appendix B, Box 7). The rising price of metals, notably gold, will further fuel increases in ASM.

As climate change impacts become more severe, economic uncertainty increases, and metal prices remain high, more people in Low-income and Lower-middle-income countries will turn to ASM in search of livelihoods. Spikes in metal prices have been associated with large-scale environmental and occupational health tragedies in the past in Zamfara (Nigeria), Dakar (Senegal), and the DR Congo. In the absence of decisive action by governments and metal purchasers, these tragedies will multiply.

Knowledge gaps. The full number of artisanal and small-scale miners globally is not known and may be substantially greater than the current World Bank estimate of 100 million, given that much ASM takes place in remote rural areas of Low-income and Lower-middle-income countries and in some places is illegal. Accurate information on the number, gender distribution, and age distribution of artisanal and small-scale miners and on the numbers of people living in ASM communities in all countries is essential for planning health and social services.

Patterns of disease, injury and premature death in artisanal and small-scale miners are poorly defined. The contribution of ASM to the global burden of disease is inadequately charted. Consequently, also the health impact of interventions in the field of ASM cannot be measured adequately.

Little is known about the local economic factors that impel populations to shift from subsistence agriculture to subsistence mining for their livelihood. ASM is a source of income diversification in many regions where farming is seasonal. In regions experiencing reduced crop yields as a result of climate- change-related alterations in weather patterns, it is possible that agricultural communities are already shifting to ASM for income stability. Better understanding of these relationships is needed, especially in supporting local development of climate adaptation strategies.

Artisanal and small-scale gold mining is – in addition to coal combustion – one of the world's two largest sources of anthropogenic mercury pollution. Yet relatively little is known about the sources of the mercury used in gold mining or how it is traded. More information is needed on the production, supply, and market for mercury used in gold extraction (Appendix B, Box 8).

Little is known about the effects of ASM on the pre- and postnatal development or on the health of infants and children. Generations of children in ASM villages are exposed prenatally to mercury and other toxic pollutants generated by mining; they ingest these toxic materials in breast milk; they play and grow up in polluted, dusty areas contaminated by metals and other hazards; and they start to work as miners even before they reach puberty. The lifelong health consequences of those exposures are very different from the health effects for healthy adult workers. Because they eat more food, drink more water, and breathe more air per Kg body weight compared to adults, children are disproportionately heavily exposed to hazardous materials such as mercury, lead or other metals. Little is known about the pre- and postnatal health hazards of mercury, lead, arsenic, cadmium, cobalt, manganese or other metals in occupationally exposed children. Clinical and epidemiological studies of children in ASM communities are urgently needed.

Recommendations. The Collegium Ramazzini calls urgently for extended efforts to minimize all hazards related to ASM. International organizations, governments at all levels – national, state or provincial, and local - and all employers - large and small, public and private - must fulfill their responsibilities to protect the health of all workers in ASM and to create occupational health and safety programs that will reduce risks of disease, injury and premature death among artisanal and small-scale miners. This call becomes particularly urgent in the context of growing global demand for minerals and metals for climate change mitigation. The Collegium Ramazzini urges non-governmental organizations to accept the challenge of reducing the grave hazards that confront artisanal and small-scale miners and their families.

Responsibilities of the International Community

As the world increases its reliance on renewable energy and demand grows accordingly for minerals and metals, the Collegium Ramazzini calls upon UN agencies and the international community to give special attention to the issue of ASM and to urge actors in the global supply chain to adopt codes of conduct that document and declare that all metals in commerce have been extracted under conditions that assure safety and health. Specifically:

- We urge the United Nations to adopt a Convention on the Safety and Health of ASM, in which member nations commit to establishing both domestic and international protections against the abuse of ASM workers and their families.
- We urge WHO and ILO to launch an international movement focused on quantifying and reducing the health hazards that arise from ASM.
- The World Bank and all other intergovernmental organizations engaged in facilitating global trade, including the International Trade Organization and the Organization for Economic Cooperation and Development, should continue to support countries managing their resources and promote decent and ethical supply chains.

Responsibilities of Governments

- It is imperative that governments put in place systems and processes for safeguarding the health and safety of artisanal and small-scale miners. Chief among these is the need to improve access to occupational health and safety services.

- Governments should develop transparent ASM management systems that include meaningful participation from all relevant stakeholders.
- Governments should decriminalize ASM in areas where it is illegal and forge collaborative partnerships to improve access to health services. They should support communities in developing a formalization framework that is protective of human and ecological health, and that protects both vulnerable groups and sensitive ecosystems.
- Governments should adopt and enforce all the ILO conventions and recommendations for health and safety in the mining industry such as the Safety and Health in Mines Convention (ILO No. 176), the Minimum Age Convention (ILO No. 138), or the Worst Forms of Child Labour Convention (ILO No. 182), the OECD's Due Diligence Guidelines and develop and adopt legislation obliging enterprises to conduct environmental and human rights due diligence in cooperation with all stakeholders involved and affected.
- Governments should adopt the basic occupational health services model that seeks to integrate occupational health to primary health services.
- Governments should provide ASM communities with tools and resources to improve occupational health and safety, community health, environmental sustainability, and remediation needs.
- Governments should establish systems that will enable miners to readily access markets for mercury- free, environmentally and socially responsible mineral extraction.

Responsibilities of Employers

- Employers have legal and moral responsibilities in all countries to provide a safe and healthful working environment to all miners in their employ.
- Multinational companies must apply the same occupational health and safety standards and environmental standards in countries where they operate – in High-income countries as well as in Low- and Lower-middle-income countries.
- Employers need to provide adequate access to remedy for victims of rights abuses and provide grievance mechanisms.

Responsibilities of Mineral Purchasers

- Mineral purchasers have the responsibility to perform due diligence upstream the supply chain of minerals by diligently investigating the supply chain of minerals they buy. It is unacceptable to purchase minerals produced in environmentally or socially harmful conditions, and it is inadequate to defer accountability due to a lack of knowledge.
- Policies for responsible mineral supply chains must be developed and followed, including traceability of minerals, refusal to do business with suppliers who cannot meet responsible production criteria, and consistent monitoring of suppliers.
- Purchasers should publicly report all measures and due diligence steps, including their risk reduction strategies, their risk management plan and their monitoring efforts. In line with OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas, companies should include those findings in their annual reports.
- Purchasers should also disclose mineral supply information to consumers, including any knowledge or lack

thereof of production or trade conditions, criteria met for sustainable and responsible ASM practices, and supply chain information about the minerals used in the product(s).

Further elaboration of these recommendations is provided in the attached Technical Appendix (B) and its Annexes.

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Appendix

This appendix gives relevant details and elaboration on hazards confronting miners and mining communities. It is structured in eight boxes, each box containing information on a subsection of risks.

- Box 1 presents a hierarchy of occupational health and safety standards for miners.
- Box 2 describes the physical hazards and injuries of ASM,
- Box 3 list the toxic hazards of ASM
- Box 4 describes the dust (4a), infectious diseases (4b), and noise (4c) hazards of ASM.
- Box 5 describes the psychosocial hazards of ASM (5a) and the particular hazards confronting women and children (5b).
- Box 6 elaborates on the impact of climate change on ASM and on the impact of ASM on the environment.
- Box 7 describes the rising demand for metals for climate change mitigation.
- Box 8 discusses gaps in research and the need for more data on ASM and its hazards.
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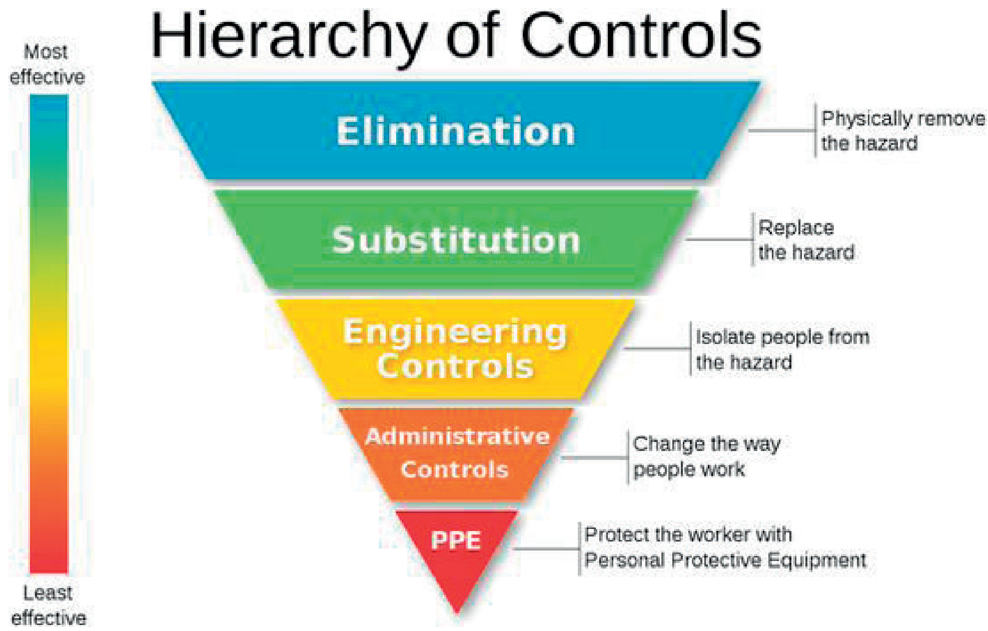
Box 1: Occupational Health and Safety: Strategies for prevention of exposure to toxic materials and hazardous conditions in ASM are classified as primordial, primary, secondary, and tertiary.

Primordial prevention	Actions designed to prevent dangerous exposures from ever occurring. **Examples:** Removal of mercury from Artisanal and Small-Scale Gold Mining
Primary prevention	Strategies for preventing disease through reducing exposures. **Examples:** Controlling workplace exposures to metals through process enclosure, exhaust ventilation, administrative controls, and personal protective equipment. While important, these measures are less effective than outright bans or substitution with less hazardous materials. Their application is guided by the *Hierarchy of Controls* framework (see below). *Standard-setting* is an important aspect of secondary prevention of exposure to toxic metals. In most countries, standard-setting is a legal as well as a scientific process and is often guided by the paradigm of *Risk Assessment* and *Risk Management*. Risk assessment/risk management is sometimes modified by application of the *Precautionary Principle* (Bose-O'Reilly & Landrigan, 2021; Landrigan et al., 2021; Nordberg et al., 2021).
Secondary prevention	Methods for early detection of disease before the appearance of symptoms, complications, or spread, through biological monitoring and health surveillance. **Example:** Blood lead and urinary mercury screening to detect exposures leading to biochemical changes related to minimal or slight symptoms (Fowler et al, 2021; Bergdahl & Skerfving, 2021). Biochemical analyses of precursors of symptoms or slight symptoms, e.g. erythrocyte zinc protoporphyrin in occupational lead exposure (Bergdahl & Skerfving, 2021).
Tertiary prevention	Methods to prevent severe consequences of disease, such as disability or death. **Examples:** Chelation therapy of acute, high-dose exposures to metals (Gerhardsson, 2021).

Application of this classification of preventive strategies to the prevention of occupational exposures in ASM is guided by the "*Hierarchy of Controls*" framework, developed by the US National Institute for Occupational Safety and Health.



Minimizing or eliminating exposures at the source before exposure ever occurs—*primordial prevention*—is the single most effective and cost-effective means of preventing hazardous exposures. It is therefore listed first in the hierarchy of controls. Personal protective equipment (PPE), while very important, is the least effective of these control strategies and thus is listed last.

Insufficient training and education is a pervasive problem in ASM. Miners are often unaware of the hazards, which are largely shaped by the social and communal setting and influenced by informal or illegal working situations and a lack of OHS management organizations. Evaluation of the few OHS programs in ASM has not been undertaken would be crucial. Long-term consequences of hazard exposure are not researched sufficiently and analogous legislation and regulation in the field of ASM lack attention and are low on the political agenda (Puplampu & Quartey, 2012; Veiga & Fadina, 2020; Veiga et al., 2006).

Box 2: Physical Hazards and Injuries

Lack of safety in mining processes is the main hazard for miners' health (World Health Organization, 2016). Artisanal and small-scale mines are poorly mechanized and use rudimentary mining methods thereby exposing themselves to a wide variety of occupational hazards. Artisanal and small-scale miners lack expertise and competency in conducting workplace risk assessments due to a lack of training and education (Hentschel et al., 2002; Wireko-Gyebi et al., 2020). This results in a multiplicity of occupational hazards that are not controlled thereby placing the health and safety of miners at risk. Poor mechanization in artisanal and small-scale mines is often associated with unsafe working processes. The miners also lack knowledge and competence in the application of the hierarchy of controls leading to unsafe workplaces. Falls from heights, mine collapses and crush injuries are common challenges within this population (World Health Organization, 2016; Kyeremateng-Amoah & Clarke, 2015; Calys-Tagoe et al., 2015; Nakua et al., 2019; Long et al., 2015). Miners are faced with extreme working conditions on a daily basis. The non- ventilated, small, and unsecured tunnels can fully or partly collapse and injure or kill workers. Blasting of tunnels with insecure explosives, or a misapplication of explosives frequently harms miners. Especially open pit mines are unstable and collapse frequently and underground water mining is considered exceptionally hazardous. Miners are often unaware of risks because training and education is absent or insufficient (Hentschel et al., 2002).

The risks result in high fatality and injury rates, including "burns, eye injuries, fractures, impalement, and in some instances physical dismemberment" (World Health Organization, 2016).

Box 3: Toxic Hazards

Various toxicological hazards occur in different types of mining. 50 - 100 million women, infants, children and men in ASM settings are exposed to *mercury* (Seccatore et al., 2014; Spiegel et al., 2005). Concentrations of mercury in biological matrices of individuals living in mining settings are measured to be at toxic levels (Steckling et al., 2017; Basu et al., 2018). Processing gold after extraction entails the smelting of amalgams, hence, research has shown that especially in artisanal and small-scale *gold* mining exposure to mercury is high among miners and communities (Gibb & O'Leary, 2014; Kristensen et al., 2014). Thereby, highly toxic elementary mercury vapor is inhaled (Spiegel et al. 2005). Consequently, several adverse health effects, especially neurological effects are observed (Ha et al., 2017; Bose-O'Reilly et al., 2017). An estimated 25% to 33% of ASGM miners show the symptoms of chronic mercury vapor intoxication, meaning 3.3-6.5 million miners globally (Steckling et al., 2017). WHO identifies elemental mercury as hazardous to the nervous system (World Health Organization, 2017). In particular mercury apor, as seen in ASGM, is also harmful to the kidney, digestive and the immune system, potentially causing fatal organ failures. Additionally, behavioral and neurological effects are described after any mode of exposure to mercury.
The WHO (World Health Organization, 2016) points out that *lead* poisoning in mining areas increases mortality and morbidity rates. Varying levels of lead, determined by geological factors, can be found in former and current ASM settings. In Kabwe/ Zambia a former zinc-lead mine is a constant source of lead exposure for the children playing and living nearby the old tailing hill, thousands of children have very high blood lead levels, and urgently the exposure from the uncovered tailing hill and the lead containing soil in the settlements has to be stopped (Bose O'Reilly et al., 2018; Yabe et al., 2018; 2015; 2020). Scavengers are still exploring the old mining side and expose themselves as well (Bose O'Reilly et al., 2018). Since 2010, several authors describe that children in a gold mine in Nigeria are highly intoxicated; approximately 400 fatalities due to lead poisoning among those children were reported (Burki, 2012; Lo et al., 2012; Dooyema et al., 2012; Greig et al., 2014; Plumlee et al., 2013; Thurtle et al., 2014; von Lindern et al., 2011). Exposure to lead at many toxic sites in Low- and Lower-middle-income countries is a well- known risk factor for the cognitive development during pregnancy (Etiang' et al., 2018), an "estimated 820,000 women of childbearing age are at risk for lead exposure at these sites" (Zajac et al., 2020). Lead is an IARC 2A carcinogen with strengthening evidence more recently (IARC, 2006).
Arsenic is released from mining and processing. Arsenic is an IARC 1 carcinogen depending on the route of exposure and species associated with skin, bladder, lung, kidney, and liver cancer (IARC, 2012a). Arsenic can adversely affect adults and children. Depending on exposure levels and circumstances, various health consequences are observed, such as skin rashes and pulmonary and cardiovascular diseases. Children and infants exposed to arsenic frequently develop neuro-developmental and -behavioral disorders (Bjørklund et al., 2020; Nyanza et al., 2020).
Cadmium is a by-product of mining. Cadmium is an IARC 1 carcinogen, mainly associated with lung cancer, but as well with cancer of the kidney and of the prostate (IARC, 2012b). Additionally cadmium deteriorates renal function, immune responses, cardiovascular and skeletal health (Basu et al., 2015).
The demand for *cobalt* sharply increases due to technological developments. Batteries used in novel electric vehicles and other technologies require cobalt as an essential resource. Mines in the Katanga Copperbelt in the Democratic Republic of Congo (DRC) are producing 60% of the metal used worldwide. 20% are estimated to originate from ASM. Environmental pollution in mining areas and lack of separation of living and working spaces, sets not only miners themselves but entire communities at risk of experiencing adverse health effects. Cobalt exposure was found to be correlated with dust exposure causing long-term damage of, inter alia, the cardio-vascular- and pulmonary system. Additionally, DNA
damage of children living in mining areas in the DRC was found, indicated by high levels of 8OHdG in urine bio-

monitoring (Banza Lubaba Nkulu et al., 2018). Indication exists that birth defects of children are related to *cobalt* and *copper* mining (van Brusselen et al., 2020). Increased sustainability of cobalt mining in terms of environment and health is urgently needed to protect the most vulnerable. Not counting as a so-called *blood metal*, which are related to high rates of conflict and violence, cobalt nowadays remains unregulated. Unlivable and hazardous conditions cannot continue to affect an increasing number of individuals who are supplying minerals which are classified as essential to sustain western economies (Banza Lubaba Nkulu et al., 2018).

Cyanide is used as an alternative to mercury in ASGM and adversely affects respiratory and cardiovascular health and is known to adversely affect the central nervous system (Fowler & Sexton, 2015). Specific data and knowledge about the health risks related to cyanide exposure in mining settings is lacking (Obiri et al., 2006).

Box 4a: Dust diseases

Respiratory diseases are worsened and caused by *silica containing dust* exposure in ASM settings. Workers and mining communities are at risk of developing silicosis, which can lead to decrease of pulmonary function and increases the risk of (silico-)tuberculosis and lung cancer. Often data collected in mining areas does not reflect the real burden of disease related to dust exposure because consequences might appear delayed once miners have already left the workforce. Sick individuals often also move from mining communities when they fall ill and are thus frequently excluded from data describing the incidence of disease. Predispositions and positive correlations between dust exposure and incidence of cancer in mining communities, as well as infectious diseases, such as tuberculosis and HIV, are also described (Basu et al., 2015; Mensah et al., 2020; Murray et al., 2011). A combination of HIV infection and silicosis has a more than additive risk of TB infection in excess of fifteen-fold (Corbett et al., 2000; Desmond et al., 2005). This is very important considering that artisanal and small-scale miners have a high burden of HIV and silicosis. It is of paramount significance for governments to put systems in place to improve access to health services for artisanal and small-scale miners (Corbett et al., 2000; Desmond et al., 2005).

Box 4b. Infectious diseases

The spread of *infectious diseases* in artisanal and small-scale miners is facilitated due to lacking *hygiene* and *sanitation* facilities and insufficient water and food safety. This concerns not only miners, but also their families, especially children and women. In combination with dust, described above, and a high prevalence of silicosis, respiratory diseases such as COVID-19 and tuberculosis are extremely hazardous. The SARS-CoV-2 pandemic disproportionately affects miners and mining communities (Calvimontes et al., 2020). Prevention efforts, such as hand washing facilities and face masks are often not available in mining communities. Production of minerals in ASM mostly continued, however at a lower rate. Lower demand from the international community led to lower prices and the international measures implemented to control COVID-19 affect trade and, therefore, the socio-economic conditions of miners. Prices of gold dropped by about 20%, diamonds and tanzanite prices by 60%-70% (Thierens & Mawala, 2020). The living and working conditions are, hence, worsened. Children were observed more frequently at mining sites because schools were closed. The supply of essentials, such as food and water, was disrupted in some places. Efforts of the governments to stop the virus from spreading shifted attention away from long-term programs, such as conflict prevention and peace-making efforts and the socioeconomic circumstances led to higher crime and robbery rates in some communities. In July 2020 international trade recovered to some extent and prices rose. The return to normal production, however, goes hand in hand with low availability of and compliance to COVID-19 prevention efforts, posing an additional risk to the vulnerable communities (Kimberly Process Civil Society Coalition (KPCSC), 2020; Thierens & Mawala, 2020).

Box 4c. Noise

Mining is characterized by high *noise* exposures which can lead to permanent noise induced hearing loss. In ASM, the lack of PPE and safety and health preventive mechanisms presents a significant challenge and is responsible for high cases of noise induced hearing loss (Hermanus, 2007). Basu et al. (2015) portrayed the setting in ASGM in Ghana, identifying high *noise* exposure in various steps of the mining process (Basu et al., 2015). *Inter alia* dynamite usage and grinding with generator-powered machines were described as such exposures. According to the WHO (2016), levels of noise in ASM can exceed acceptable levels for preventing hearing loss. Additionally, cardiovascular, as well as cognitive and behavioral disabilities, are correlated to noise exposure in ASM.

Box 5a: Psychosocial hazards

In addition to biological hazards, the miners' health is deteriorated by psychosocial hazards (Basu et al., 2015). The quality of life is negatively affected (Becker et al., 2020; Basu et al., 2015). It is of great mportance to recognize that those benefiting from mining are situated in the Global North and consistently externalize environmental and health risks and costs to countries in the Global South, intensifying these psychosocial hazards.)

A variety of biopsychosocial hazards increase morbidity and mortality rates among miners. A lack of Occupational Health and Safety (OHS) regulations worsens the exposure and the consequences of exposure (Tsang et al., 2019). Psychosocial hazards include a decline in biodiversity and a displacement of indigenous communities. Prostitution, criminal activities, violence and substance abuse are frequently observed in the mining setting. The lack of healthcare facilities and efforts to formalize health insurance and social security mechanisms, as well as the present informal or illegal employment situations contribute to hazardous living and working conditions. Women, in the role of workers, caretakers and mothers, are exposed to a variety of risks in mining settings. Child labor is a main risk factor for children living in mining communities (Bose-O`Reilly et al., 2010; Amon et al., 2012).

Miners, their families and the communities they live in, are exposed to **prostitution, violence, criminal activities and substance abuse** (Basu et al., 2015).

Coltan mines, almost exclusively found in the east of the DRC, are often at the center of violent conflicts; militia groups control these territories exploiting workers. These *blood minerals* are mostly exported, highlighting a responsibility of the internationals to ensure sustainable, transparent and non-violent extraction of coltan (Pole Institute, 2010). The requirement to only export resources labeled '*conflict-free*' to counteract violence and war was implemented for Congolese minerals. This ban, however, is criticized sharply for lowering the income and, thereby, worsening the conditions of miners in geographically remote areas, where control and, therefore, labeling is impossible. Secondly, strain is put on public authorities in a politically unstable setting where powers and legitimacy are not easily defined and production remains informal to a great majority (Geenen, 2012). *Tin, tantalum,* and *tungsten* (3T minerals), as well as other minerals, are still part of the armed conflict in the DRC today. Notably, however, these are not a cause but a symptom of instability, conflict and (Vogel, 2018).

These arguments strongly relate to current formalization efforts. Top-down formalization efforts, in an environment where most employment is informal, frequently worsen living and working conditions of employees. Livelihoods that depend on the income from ASM are put under pressure by an increase of legitimacy to cooperate mines. A combination of bottom-up and top-down efforts has to be found (Geenen, 2012).

Box 5b. Hazards confronting women and children

Women are often affected disproportionately. Estimates suggest up to 50% of miners are female in some African artisanal and small-scale mines (Hinton et al., 2003). Because they are mainly involved in processing or transporting ore, they may not be recognized as miners or included in the statistics (Susapu & Crispin, 2001). Often mining is experienced as a women's sole way of gaining financial independence. It is reported that women engage in informal and illegal activities more frequently than men (Mudzwiti et al., 2015). As workers in mines, or as those responsible for processing the ore, women are exposed to all hazards described above. Women's reproductive health suffers and maternal health decreases. In ASGM, smelting is commonly seen as the women's task and results in exposure to mercury fumes. This exposure can span from prenatal to adulthood, with adverse neurological effects on whole generations in working as artisanal and small-scale miners (Reuben et al. 2020) Additionally, women are at a high risk due to isolation in mining settings and physical and sexual abuse. Sexual transmitted diseases (STDs) are frequently reported among women. As a result of structural gender inequalities women benefit from even fewer OHS services than men (Tsang et al., 2019; World Health Organization, 2016; Werthmann, 2009; Hentschel et al., 2002)

Child labor in ASM is common and requires specific attention. According to the ILO (2019) about one million children worldwide are working in mines. Sometimes up to half of the miners are below the age of 15. These children work in "life-threatening conditions, subject to violence, extortion and intimidation" (ILO, 2019), not able to seize some of their fundamental human rights. Since life chances are largely defined by early life years, growing up in mining communities and later working in mines diminishes an individual's potential drastically. Firstly, weak maternal health determines an infant's start to life and, thereby, his or her later health state. Children laborers have reduced access to education and, hence, few chances to escape from the hazardous settings. The biological hazards described above present a particular risk to the still developing children. Mercury can affect fetuses and children extensively and

adverse health effects are reported. Malnutrition and adverse musculoskeletal consequences are described to occur among child miners (Hinton et al., 2003; Grigg, 2004; ATSDR, 1999). Because of the high mobility of ASM communities, the presence of many young men who are without their families, the daily flow of cash, and the high rates of alcohol and substance abuse, prostitution is part and parcel of mining life (Hayes & Perks, 2012; Basu et al., 2015). Like their mothers, girls are exposed to sexual and gender-based violence and exploitation, often resulting in pregnancies and STDs. Boys are not excluded from forced child prostitution (International Labour Organization, 1999). In addition, substance abuse is reported among child miners. Financial incentives and peer pressure are usually the reasons children engage in mining activities (Amon et al., 2012; Bose-O'Reilly et al., 2010; Mudzwiti et al., 2015; Hentschel et al., 2002).

Box 6: Environmental impacts and climate change

All stages of ASM negatively impact the environment, contribute to climate change and are responsible for declines in biodiversity. Landscape destruction occurs when exploring, exploiting and closing mines. Furthermore, toxicological and waste pollution of waters, soil, and air is related to the processing of minerals and inappropriate disposal. Due to a lack of training and education, and formalization and control in the sector, these environmental damages continue to worsen the situation in mining settings. Indigenous communities are increasingly displaced, cultural deprivation accompanies the environmental devastation, therefore, suffering the long-term consequences of the environmental damage (Hentschel et al., 2002; Nkuba, et al., 2019; Kahhat et al., 2019; Niane et al., 2019; Diringer et al., 2020). These environmental impacts urgently need increased attention.

Box 7: Rising global demand for metals

It is widely recognized that mineral demand will continue to increase in the coming decades. One critical factor in this increase is the impact of climate change. By 2050, mineral production will need to meet rapidly growing demand for low-carbon energy technology such as solar and wind power, e-vehicles, and the batteries needed to store energy for "green" energy alternatives (Hund et al., 2020). Few can predict the impact of a 450% increase in cobalt demand on the Democratic Republic of Congo, which holds roughly half of the world's cobalt reserves, and where 20-30% is produced via ASM (Shedd et al., 2017; Hund et al., 2020)

Box 8: Identification of data gaps and lack of knowledge

It is clear that low-carbon technologies are mineral intensive and will require large increases in global metal production. What isn't clear is how climate-impacted populations shift from subsistence agriculture to subsistence mining. ASM is a source of income diversification in many regions where farming is seasonal; in regions experiencing reduced crop yields as a result of altered weather patterns, it is possible that agricultural communities are already shifting to ASM for income stability (UNEP, 2012; Lahiri-Dutt, 2018; Odell et al., 2018; Okoh & Hilson, 2011). Better understanding of this relationship is needed, especially in supporting local development of sustainable climate adaptation strategies.

ASGM is the largest source of global anthropogenic mercury release (UN Environment, 2019), but relatively little is known about where the mercury is sourced and traded. More information is needed on the production, supply, and market for mercury used in gold extraction.

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