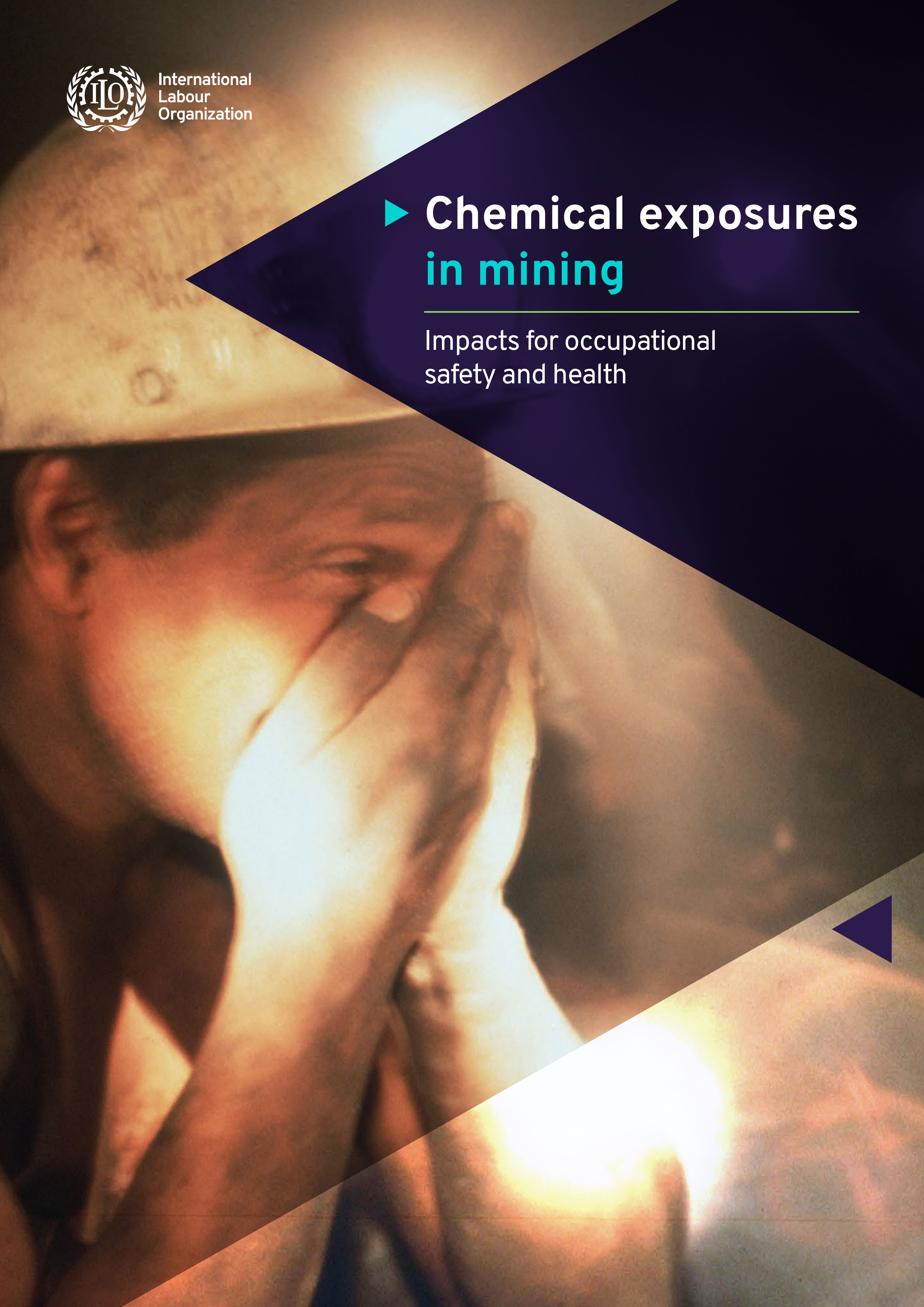

Chemical exposures in mining

Impacts for occupational safety and health

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Contents

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Executive Summary

Occupational exposure to chemicals in the mining sector continues to pose a major safety and health risk to workers globally. A number of toxic chemicals are commonly used in mining practices, including mercury, cyanide, sulfuric acid and solvents, as well as dangerous explosives. It is estimated that up to 19 million miners are exposed to mercury alone in artisanal and small-scale mining (ASM) operations, giving an indication of the scale of the problem. Occupational exposure to these hazardous chemicals can severely impact body systems and organs, leading to disability, life-long illness and even death. Workers in low- and middle-income countries (LMICs) and in informal settings are particularly at risk, with health effects undiagnosed or misattributed, unrecorded and unaddressed.

The International Labour Organization (ILO) has long recognized that protecting workers from hazardous chemicals, including those used in mining, is essential to ensuring safe and healthy workforces and populations. The inclusion of a 'safe and healthy working environment' within the ILO's framework of fundamental principles and rights at work provides a framework for action to protect miners against hazardous chemicals exposures in mines. A national occupational safety and health (OSH) systems approach is needed, leveraging ratified international labour standards, global platforms and initiatives, as well as practical enterprise level actions that prioritize prevention and elimination. Key ILO instruments in this area include Chemicals Convention (No. 170) and Recommendation (No. 177), 1990, and the Safety and Health in Mines Convention (No. 176) and Recommendation (No. 183), 1995, as well as the fundamental OSH Conventions, the Occupational Safety and Health Convention, 1981 (No. 155) and the Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187). A strong OSH system is critical for the effective implementation of policies and programmes on OSH and the sound management of chemicals at the enterprise level. Targeted strategies include the execution of a workplace level strategy involving chemical identification, comprehensive risk assessment and implementation of control measures following the Hierarchy of Controls.

Acronyms

ASGM	Artisanal and small-scale gold mining
ASM	Artisanal and small-scale mining
CMMVI	Chronic metallic mercury vapour intoxication
CSE	Chronic solvent-induced encephalopathy
DALY	Disability-adjusted life year
DPM	Diesel particulate matter
GBD	Global Burden of Disease
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
ICMM	International Council on Mining & Metals
ILO	International Labour Organization
LMIC	Low- and middle-income country
LSM	Large-scale mining
NAP	National Action Plan
OEL	Occupational exposure limit
OSH	Occupational safety and health
PPE	Personal protective equipment
SAICM	Strategic Approach to International Chemicals Management
SDG	Sustainable Development Goals
SDS	Safety data sheets
TLV	Threshold limit value
TWA	Time weighted average
WHO	World Health Organization
WOA	Whole ore amalgamation

Background

Introduction

Mining is a highly hazardous occupation. Explosions, flooding, toxic air, rockfalls and extreme temperatures are some of the perilous hazards and associated risks observed in mining. Although the industry only employs one per cent of the global workforce, it is responsible for about eight per cent of fatal accidents at work (ILO 2015). Occupational exposure to chemicals specifically poses a major safety and health risk to miners around the world. When it comes to chemical hazards, mercury, cyanide, sulfuric acid and solvents are commonly used in mining practices, whilst silica dust and diesel particulate matter (DPM) are frequently generated as by-products. Various explosives are used for blasting tunnels and other excavation work. These toxic chemicals can severely impact body systems and organs, leading to disability, chronic illness and even death.

All these deaths, injuries and illnesses are entirely preventable. Indeed, the large-scale mining (LSM) sector has become more safety conscious, with fewer fatalities reported in recent years. Unfortunately, the 44.75 million mine workers in artisanal and small-scale mining (ASM) are still exposed to dangerous working conditions, with inadequate occupational safety and health (OSH) protections (Delve 2020). This workforce includes over one million children and other vulnerable groups, including pregnant women and migrant populations (ILO 2019). Poverty, poor technical and financial support, and limited training contribute to the frequent injuries, fatalities and recurring illness in mining areas (Hilson and McQuilken 2014). Yet, ASM has experienced explosive growth in recent years due to rising mineral prices and a lack of alternative employment opportunities in rural populations (IGF 2018).

The International Labour Organization (ILO) has been dealing with labour and social issues in the mining industry since its early days, making considerable efforts to improve the work and life of miners - from the adoption of the Hours of Work (Coal Mines) Convention (No. 31) in 1931, to the Safety and Health in Mines Convention (No. 176), adopted in 1995. In particular, the ILO has long recognized that the protection of workers from hazardous chemicals is essential for ensuring healthy populations, as well as sustainable environments. Improving OSH at all mining sites is also paramount to achieving Sustainable Development Goal (SDG) 8: “Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all”. Nevertheless, miners continue to be highly exposed to chemicals, with workers in low- and middle-income countries (LMICs) and in informal settings particularly at risk.

There is a need to take action and implement a range of effective measures to prevent harm to mine workers, their families and wider communities. This document aims to provide information and raise awareness on the broader use of chemicals used in the mining sector.

> A ‘mine’ means any place where mechanical disturbance of the ground takes place for the purpose of prospecting for or producing coal, mineral-bearing substances, placer minerals, rock, limestone, peat, clay, sand or gravel and oil sands and shales; it includes all machinery, equipment, building and civil engineering structures (such as tailings dams and waste-rock and overburden dumps) used in conjunction with mining and the subsequent on-site treatment of the products or servicing of these activities. This definition covers the main purpose of the activity, namely the search for, the extraction of and the related crushing, grinding, concentrating or washing of a product.

▶ ILO definition of a mine (Safety and health in mines, Report V(1), International Labour Conference, 81st Session, Geneva, 1994)


Worker in the control center of the Boliden Garpenberg underground mine in Sweden. © Marcel Crozet/ ILO.

The mining sector

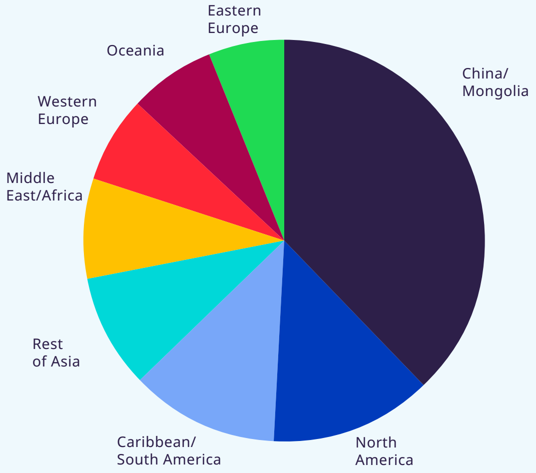
The mining sector is crucial to the world's economy. Minerals and mineral products are the foundation of numerous industries and some form of mining is carried out in most countries of the world. The demand for mining activities across the globe is rising, with the need for certain mined minerals projected to increase exponentially in the coming decades. For example, manufacturing the required technologies and infrastructure for renewable energy production will drive an increase in the demand of many metals (Sonter et al. 2020). This includes cobalt, used in the lithium-ion batteries of electric vehicles, which is often mined in hazardous informal mines with minimal OSH protections (Avidsson et al. 2022).

Mining facts & figures (Garside 2021)

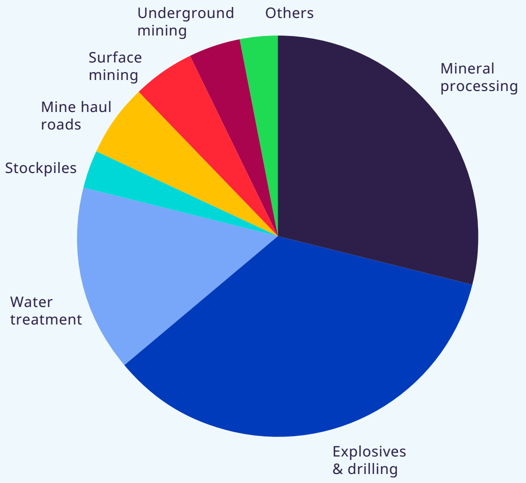
- In terms of volume, the most exploited commodities worldwide are **iron ore**, **coal**, **potash** and **copper**.
- China, Indonesia and India are the largest coal-producing countries.
- China is becoming the top mining country for many commodities, especially for highly demanded rare earths, of which China produced nearly 58 per cent of the global production in 2020.
- China is the world's leading country in the mine production of gold.

The mining chemicals market, in particular, was valued at US$9.89 billion in 2020 and is set to be worth US$15.57 billion by 2028 (Grand View Research 2021). Chemicals are used in surface and underground mining for mineral processing, explosives and drilling, water treatment, stockpiles and mine haul roads. Figure 1 and Figure 2 show the world consumption of mining chemicals by region and application.

▶ Figure 1. World consumption of mining chemicals, by region (IHS Markit 2017)



▶ Figure 2. Global mining chemicals market, share by application (Grand View Research 2021)



▶ Large-scale mining (LSM) versus artisanal and small-scale mining (ASM)

Increased mechanization and enhancements to OSH by governments and industrial mining companies has led to improvements in worksite safety. For example, in 2020, the International Council on Mining & Metals (ICMM) reported 44 fatalities amongst its member companies, a considerable improvement over the 287 deaths caused by the collapse of the Brumadinho Dam the previous year.

Often little or no chemicals are used in LSM due to advanced mechanized technologies. Additionally miners are often kept away from direct contact with hazards, by using remote-controlled equipment and control monitors.

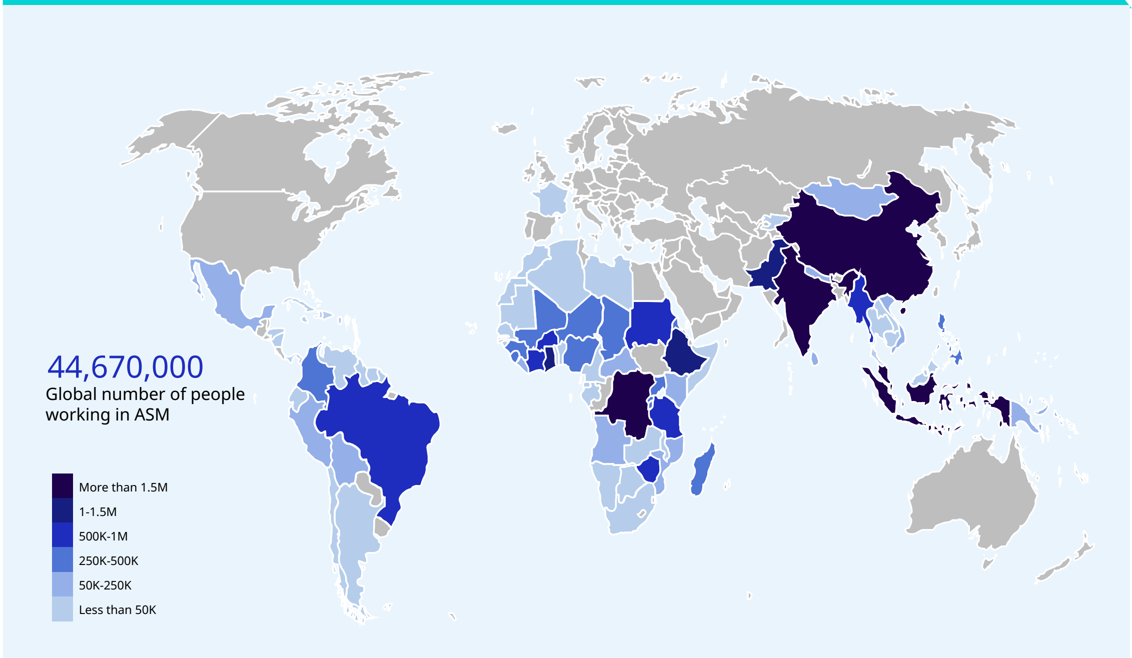
The Boliden Garpenberg Mine, Sweden – one of the most automated and efficient underground mining operations on the globe. © Marcel Crozet/ ILO.

At 1,054 meters underground, an operator oversees work on a control monitor, far from the noise and humid heat of the galleries.

An operator handles a remote controlled rig and oversees its work on a control monitor.

ASM is a major source of mineral resources, with one of the world's largest mining workforces (Delve 2020). It is the primary source of employment for at least 44.75 million people across 80 countries worldwide (Delve 2020). 30 per cent of this number are women, and children as young as ten years old are frequently involved in mining tasks. ASM produces around 15 to 20 per cent of global minerals, including 80 per cent of sapphires, 20 per cent of gold, and 20 per cent of diamonds (World Bank 2013). It is also a major producer of raw materials strategic to electronics manufacturing, such as tantalum and tin (Sidorenko et al. 2020). Figure 3 and Figure 4 show a map of the number of people working in ASM globally and the top ten ASM countries.

▶ **Figure 3. Number of people working in ASM globally (Source: Delve 2020)**



▶ **Figure 4: Top ten ASM countries by number of people working in ASM (Source: Delve 2020)**

Country	No. working in ASM
India	15,000,000
China	9,000,000
Indonesia	3,600,000
Democratic Republic of Congo	2,000,000
Ethiopia	1,260,000
Ghana	1,100,000
Burkina Faso	1,000,000
Zimbabwe	1,000,000
Sudan	1,000,000
Tanzania	1,000,000

80 to 90 per cent of ASM activity operates informally, with workers in many mining countries not covered by labour legislation (Perks and McQuilken 2020). Informal ASM operations exploit small deposits in rural areas, where workers often have limited alternative employment opportunities. The work is labour intensive, low paying, extremely hazardous, and almost always avoided if other work is available. Worksites frequently operate illegally and receive little in the way of supervision or support from authorities.

Accident rates in small-scale mines are routinely six or seven times higher than in larger operations, even in industrialized countries (ILO 2015). It is widely acknowledged however, that accidents in ASM are underreported (ILO 1999). In India, for example, whilst official statistics reported 120 deaths from mining in 2018, the real death toll was estimated to be around 20,000 for that year (Delve 2020). These numbers would increase significantly when considering that long-term health impacts, a particular concern

> Occupational safety and health (OSH) are important issues for small-scale mines and their communities. The lack of reliable data and difficulties in its collection makes it more difficult to develop effective assistance programmes and to improve safety and health performance.

ILO (Tripartite Meeting on Social and Labour Issues in Small-scale Mines, 1999)

for chemical exposures, are not even considered. LSM industries in the United States of America and South Africa had similar fatality rates in the 1970s and 1980s respectively, as ASM did in 1999. This makes improved safety in ASM a feasible proposition if regulated OSH procedures are introduced and implemented.

Whereas work on formal LSM has taken a more central role in the ILO's work, ASM has now also become an important issue, given its informal nature in many developing countries and continued rapid expansion. Work in this subsector is guided by the 1999 Conclusions of the ILO Tripartite Meeting on Social and Labour Issues in Small-scale Mines, which addressed safety and health, child labour, gender and environmental issues in small-scale mining (ILO 1999).

Women in ASM

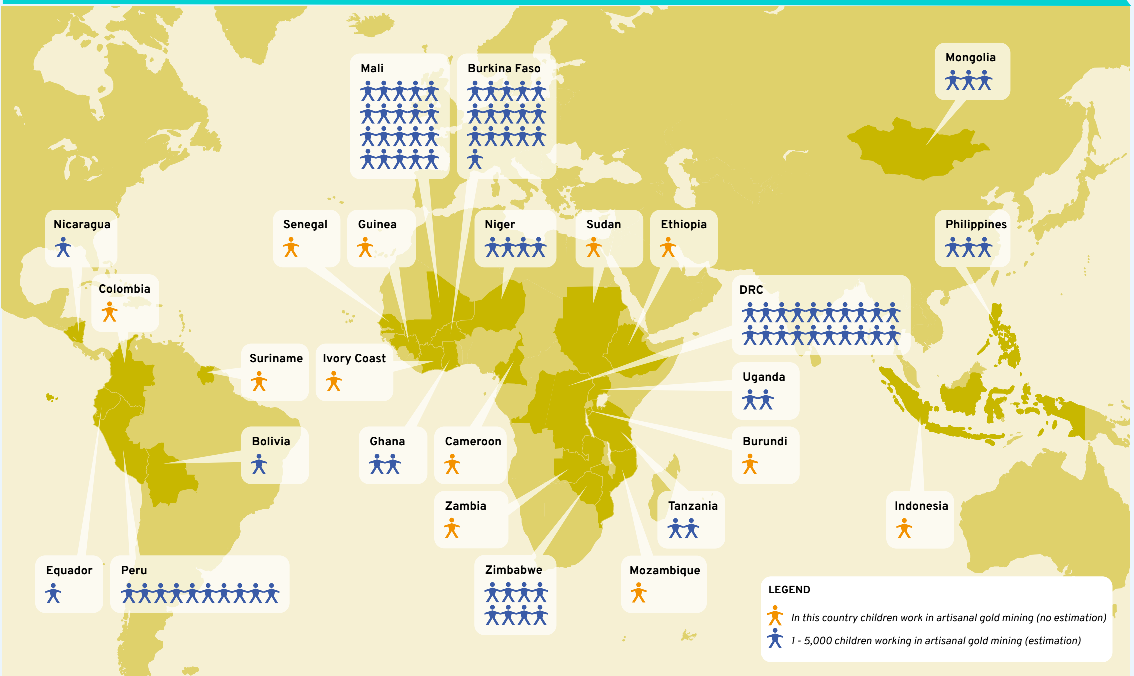
Women play a significant role in ASM, as they are estimated to make up around 30 per cent of the total global workforce, and up to 50 per cent in Africa (IGF 2018). Yet, 60 per cent of ASM countries do not have published data on female participation in the sector (Delve 2020). Men work primarily in mines and are also involved in decisions regarding mining exploration, prospecting and benefits distribution (Eftimie et al. 2012). Women are usually not involved in digging and other heavy mining activities, but participate in activities like sluicing, panning, mercury-gold amalgamation, amalgam decomposition, cleaning and food provision (IGF 2018). Tasks carried out by women vary according to region. For example, in Bolivia, women mainly gather and process ore, often using sledgehammers, whilst in Africa they are involved in all aspects of mining, including digging, crushing, transporting, sorting, processing and trading (WHO 2016). In addition to issues such as financial exploitation, women are at increased risk of adverse health impacts, notably from reproductive hazards, as they often perform ore purification using mercury or cyanide (Eftimie et al. 2009). They also frequently encounter workplace discrimination, unequal pay, sexual harassment and do not enjoy the same rights, as they are unable to own land and mining titles (ILO 2021a).

Children in ASM

More than one million children are engaged in child labour in mines and quarries (ILO 2019). In some areas the problem is particularly acute. For example, it is estimated that in Burkina Faso and Niger, some 30 to 50 per cent of the gold mine workforce is comprised of children, predominantly under the age of 15 (ILO 2006). 20 per cent of artisanal gold miners in Mali are children (Schipper et al. 2015). Children engage in a wide range of hazardous activities, from working in underground shafts with poor ventilation, to handling mercury to amalgamate gold with bare hands (ILO 2019).

ASM has a poor reputation when it comes to child labour and the ILO considers mining as a worst form of child labour due to the harsh working conditions, handling and exposure to toxic chemicals and the vulnerability of young women and girls to sexual and gender-based violence. Figure 5 shows child labour in ASM worldwide.

Figure 5: Child labour in ASM worldwide (Schipper et al. 2015)



Case study:
Children in cobalt mines in the Democratic Republic of Congo

Increasing evidence has demonstrated the presence of child labour in cobalt and coltran mines (ILO 2019). These minerals are used in portable electronic devices and rechargeable batteries, including the batteries of electric cars. More than half of the world's supply of cobalt comes from the Democratic Republic of Congo (Statista 2020), where children as young as seven years old work in life-threatening conditions, subject to violence, extortion and intimidation (ILO 2019).

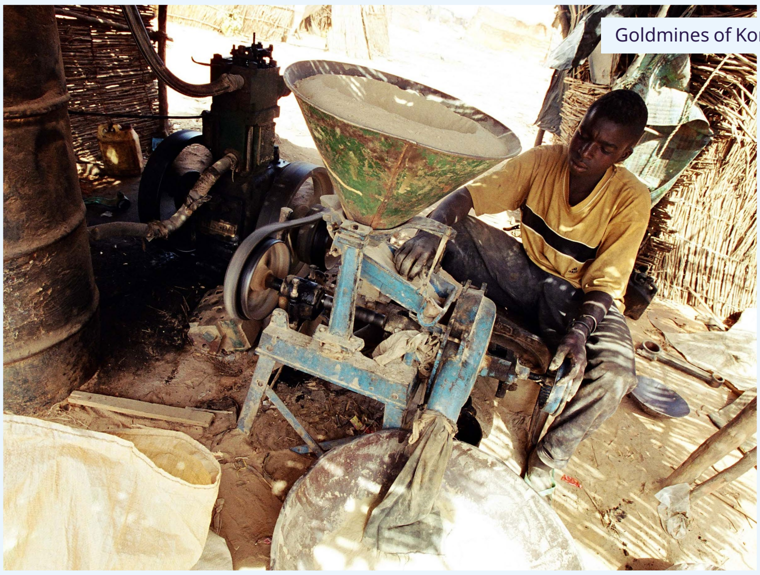
Spotlight on artisanal and small-scale gold mining (ASGM)

ASGM continues to be the largest user of mercury globally, with an estimated 14 to 19 million people working in the industry, in 70 countries (Steckling et al. 2017). Approximately 4.5 million of these workers are women and 600,000 are children (UNEP 2019). ASGM largely occurs in low- and middle-income countries (LMIC), primarily in East and South-East Asia, Sub-Saharan Africa and South America, which account for the great majority of the burden of occupational exposure to mercury (UNEP 2017). The extent of ASGM has steadily increased since the year 2000 and shows no sign of falling off as long as the price of gold remains high (UNEP 2017). Gold is extracted using semi-mechanized and low-tech methods, with workers exposed to dangerous chemicals, including mercury, cyanide and silica dust.

ASGM demographics vary considerably, with people of all ages working on different mining tasks. The work is often informal, and mining authorities may lack funding and the resources to effectively supervize and monitor ASGM. Techniques are often inefficient, product quantities are small and profits are low (Barry 1996). Despite the risks however, ASGM can represent an economic opportunity for communities where alternative livelihoods are scarce or where people are employed in seasonal work (Haundi et al. 2021). Notably, the industry has the potential to alleviate poverty in rural populations and contribute to economic development (Neumann et al. 2019). For example, a recent study of the socio-economic benefits of ASGM in Malawi found that ASGM had helped alleviate poverty in places and situations where other industries could not (Haundi et al. 2021).

Case study: ASGM in Colombia

ASGM makes up 94 per cent of gold mining operations in Colombia, of which 60 per cent are illegal, often financed by organized crime (UNODC 2016). Over 300,000 families work in the sector, due to reasons such as ease of access, informal operating circumstances and the chance to earn an income (Veiga and Marshall 2019). Gold mining generates approximately US$2.4 billion in revenue (ANM 2018).



Goldmines of Komabangou. Niger.

Mining, chemicals and health

A chemical substance is an element, compound or mixture which may be present in the workplace in the form of a liquid, solid or gas. Mine workers may be exposed to hazardous chemicals which are used as part of a production process, as well as to chemicals generated by a process or used in maintenance activities. For example, unclaimed ore and spent processing chemicals, known as tailings, are often discharged into waste streams, which may be an extra source of exposure (Rozon-Ramilo et al. 2011). Absorption can occur through inhalation, ingestion or dermal contact (Figure 6). Chemical substances may also be a fire or explosive hazard in the workplace.

Numerous health impacts have been associated with the different chemicals used in mining, with the prevalence and severity of occupational diseases dependent on the type of ore mined, the contaminants present and the levels and duration of exposure. Chemicals can have acute and/or chronic health effects, with or without a latency period. Due to poor ventilation in confined spaces, toxic gases are not always able to disperse and can therefore build up in the mine. Workers may also be exposed when handling chemicals without proper OSH procedures and inadequate engineering and administrative controls and/or personal protective equipment (PPE).

Figure 6. Chemical absorption/exposures – key facts

Inhalation	▶ Inhalation is the main route of exposure for some chemicals. For example, 80 per cent of inhaled mercury vapour is absorbed in the lungs (Park and Zheng 2012). ▶ Poorly ventilated, warm, indoor spaces are of particular concern in cases of airborne vapours.
Dermal absorption	▶ Dermal absorption may occur if chemicals are handled inappropriately or if they are spilled and not cleaned properly.
Ingestion	▶ Ingestion of chemicals in the workplace may occur where hygiene practices are limited, for example from eating/smoking when hands are dirty. ▶ Exposure may also occur from chemical-contaminated food sources, for example, if workers live near their worksites.

Key chemicals

Mercury (Hg)

Mercury is a highly dangerous heavy metal that persists in the environment. It is a serious issue globally, with the World Health Organization (WHO) identifying mercury as one of the top ten chemicals of major public health concern (WHO 2017). Workers in mining industries may be exposed to mercury in ASGM operations, primary mercury mining and the mining of other ores.

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Mercury exposure in ASGM

ASGM workers were identified as one of four populations of concern for mercury exposures, above general population levels (Basu et al. 2018). Gold extraction with mercury is the most commonly used extraction method in ASGM, because it is cheap, quick and easy, and can be done by one person independently (UNEP 2012). Whole-ore amalgamation (WOA), where mercury is added directly to the gold ore during the grinding or crushing process, has been identified as worst practice, to be eliminated under Annex C of the Minamata Convention on Mercury. This process is most common in Bolivia, China, Colombia, Ecuador, Indonesia, Peru, the Philippines, Suriname and Venezuela (UNEP 2017).

Whole ore amalgamation (WOA)

WOA is a major source of pollution globally, however, it is a cheap, quick and easy way for miners to extract gold. WOA is considered poor practice because:

- Mercury use ranges from high (4 parts mercury for each part gold recovered) to very high (20 parts mercury for every part gold or higher). In extreme cases, for example where ore is rich in silver, the ratio can be 50 to 1.
- WOA is inefficient - it rarely captures more than 30 per cent of the gold and results in major losses of mercury to tailings (waste material).
- Large amounts of mercury are lost to the tailings, because the mechanical process produces tiny mercury droplets ("floured mercury") that are too dispersed to capture. The result is mercury contaminated sites that are very difficult to clean-up.

Mercury use in ASGM is particularly hazardous and workers are at high risk of toxic exposures specifically due to the way mercury is handled and used. The most direct route of exposure is via inhalation of mercury vapour from heated amalgam, for example during the open burning process or smelting (WHO 2016). Mercury vapours in the air around amalgam burning sites can be alarmingly high and usually exceed the WHO limit for public exposure of 1.0 μg/m^3 (UNEP 2012). This means that all workers in the area may be exposed to hazardous mercury levels, even those not directly handling mercury (Gibb and O'Leary 2014). Workers can also be exposed to mercury vapour if liquid mercury is not properly stored, if surfaces are contaminated or they are in contact with contaminated waste material (WHO 2016).

Biological matrices using urine, blood and hair can be used to measure mercury exposure. Urinary mercury can be hugely elevated for those involved in both amalgamation and heating/burning processes. For example, studies report urinary mercury concentrations well above 50 μg mercury/g-creatinine, a urinary concentration where renal tubular effects are believed to occur, and 100 μg mercury/g-creatinine, a urinary concentration where the probability of developing the classical neurological signs of mercury intoxication is "high" (WHO 2013).

Case study: Mercury exposure in ASGM communities in Colombia (Calao-Ramos et al. 2021)

A study of 238 ASGM miners in Colombia assessed total mercury in blood, urine and hair samples, as well as methylmercury in hair. Approximately 40 per cent of miners showed mercury concentrations in blood, urine and/or hair above WHO thresholds. Miners burning amalgams showed significantly higher concentrations then miners not involved in this process, with values 7-, 7- and 8-fold higher in blood, urine and hair respectively.

Other mining activities involving mercury

Aside from ASGM, workers in other mining industries may also be exposed to mercury. These include:

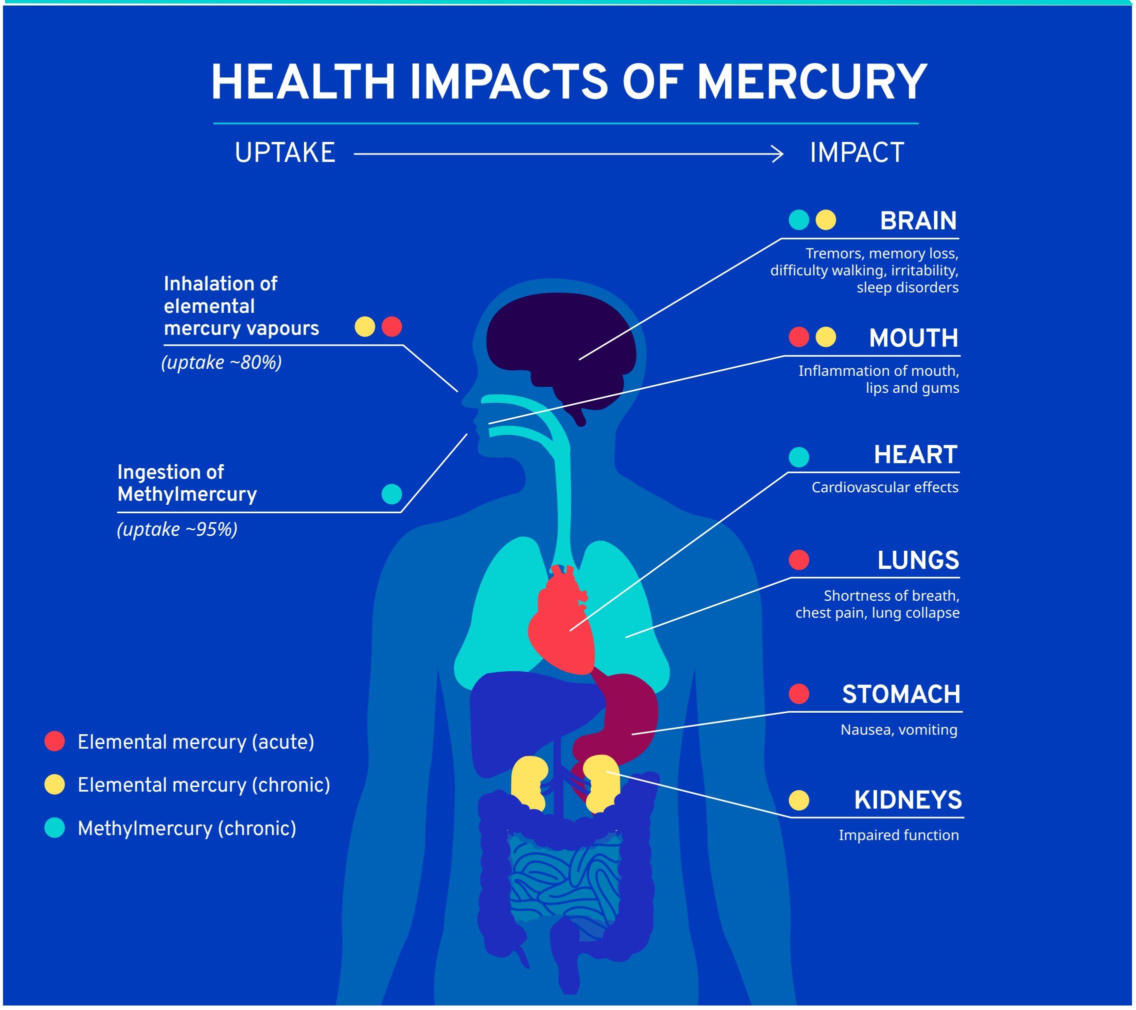
- **Primary mercury mining:** Mercury is currently only mined in China, Mexico, Indonesia and the Kyrgyz Republic (UNEP 2017). In 2019, the world production of mercury from mining was 4,000 metric tonnes and the leading global producer was China (3,500 metric tons) (USGS 2020). Both China and Mexico have ratified the Minamata Convention in 2016 and 2015, so all existing mines are to be phased out within 15 years of that date.
- **Non-ferrous ores:** Mercury may appear as a trace contaminant in other non-ferrous ores, including zinc, gold, lead and copper ores. By-product mercury is generated from non-ferrous mining operations, most of which goes to disposal or is released into the environment (AMAP/UNEP 2013).

Health impacts of mercury exposure

Key points

- Between 25 and 33 per cent of ASGM miners occupationally exposed to mercury are estimated to suffer from chronic metallic mercury vapour intoxication (CMMVI) (Steckling et al. 2017).
- ASGM workers frequently have urinary mercury concentrations above the WHO threshold, beyond which there is a high probability of developing classic neurological signs of mercury poisoning.
- Global burden of mercury exposure for ASGM alone was estimated to be 14-19 million (Steckling et al. 2017).
- The Global Burden of Disease (GBD) from ASGM alone was estimated to be over 2 million disability-adjusted life years (DALYs) (Steckling et al. 2017).

Figure 7: Major health impacts of mercury exposure (AGC 2020)



Exposure to mercury, even in small amounts, may adversely impact the nervous, digestive and immune systems, as well as specific organs, such as the liver, heart, brain, lungs, kidneys, skin and eyes (WHO 2021a) (Figure 7).

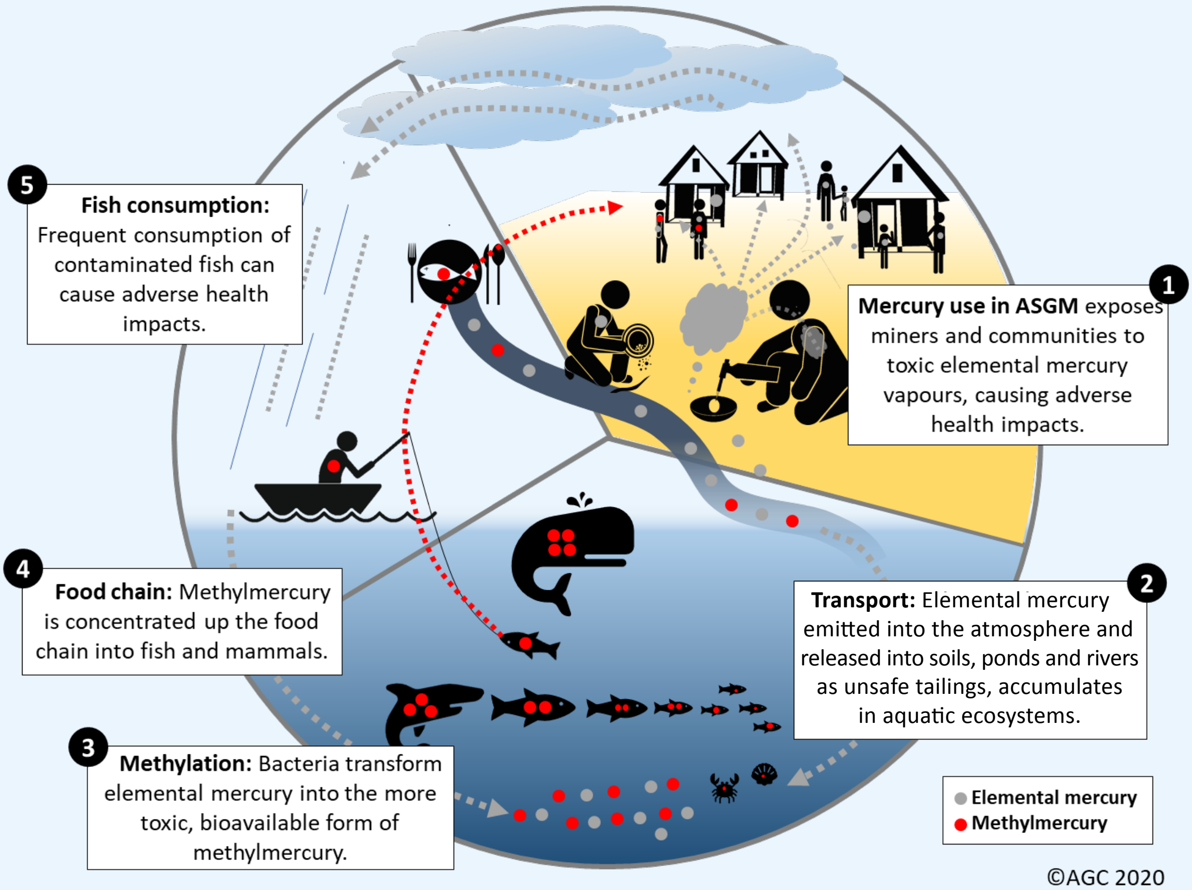
Inhalation of elemental mercury vapour can produce harmful effects on the nervous, digestive and immune systems, lungs and kidneys (WHO 2017). In high quantities, inhalational exposures can also lead to respiratory failure and death (Landrigan and Etzel 2013).

The central nervous system is the most sensitive target for elemental mercury exposure, with chronic and acute exposures eliciting similar neurological effects. Neurotoxic symptoms may include tremors, insomnia, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunction (WHO 2021a). The peripheral nervous system may also be affected, resulting in slowed sensory and motor nerve conduction velocities.

Respiratory tract infection and renal damage may occur at higher mercury exposures, as well as cardiac effects, such as hypertension, heart palpitations and increased heart rate (Poulin and Gibb 2008).

An additional source of mercury exposure for mine workers may be through the consumption of methylmercury-contaminated fish and seafood from environmental pollution (Figure 8), leading to a double burden of occupational and environmental exposure. The central nervous system is the major target organ following exposure to methylmercury and most other organic mercury compounds. Neurological symptoms similar to those observed following elemental mercury exposure may be observed, including tremors, emotional changes, headaches, weight loss and insomnia. Pregnant women and their foetuses are particularly at risk and transplacental exposure may result in neurodevelopmental problems in the developing foetus (WHO 2021a).

Figure 8: Impacts of mercury use in ASGM on human health and the environment



Further evidence from ASGM

A large systematic review of over 60 studies by Gibb and O'Leary (2014) looked at the health impacts of workers in ASGM. It found that workers, including many children, were exposed to dangerously high levels of elemental mercury vapour, as evidenced by urinary mercury concentrations. The most common adverse health impacts reported among workers were neurological effects, including tremor, ataxia, memory problems and vision disorders.

Another study found that between 25 per cent and 33 per cent of miners were estimated to suffer from chronic metallic mercury vapour intoxication (CMMVI) (Steckling et al. 2017). Symptoms of CMMVI include ataxia, dysdiadochokinesia, tremor and restricted performance in neuropsychological testing (Steckling et al. 2017). The resulting Global Burden of Disease (GBD) was estimated to range from 1.22 to 2.39 million disability-adjusted life years (DALYs), with the highest burden in the WHO African Region (Steckling et al. 2017).

The WHO considers urinary mercury concentrations of 100 µg Hg/g creatinine as the threshold beyond which there is a high probability of developing classic neurological signs of mercury poisoning. Numerous studies have shown concentrations of well above 100 µg Hg/g creatinine in miners, with concentrations particularly high for those making the mercury-ore mixture or heating amalgam (Harari et al. 2012). Examples of high concentrations in urine observed in ASGM include a study conducted in Burkina Faso, which showed average urinary mercury among gold traders of 299.1 µg Hg/g creatinine, and another in Venezuela, where the average urinary mercury concentration was 148 µg Hg/g creatinine, with the highest recorded at 912 µg Hg/g creatinine (Drake et al. 2001). Gold dealers are also thought to be frequently exposed to mercury vapour (Tomicic et al. 2011).

A study carried out in Indonesia and Zimbabwe by Bose-O'Reilly examined mercury exposure in 80 children aged between 9 and 17 working in ASGM. It reported that children working with mercury showed symptoms of mercury intoxication, including ataxia and dysdiadochokinesia, as well as high levels of urinary mercury compared to non-exposed children (Bose-O'Reilly et al. 2008). When considering the numbers of children involved in ASGM, the potential burden of disease in adulthood for former ASGM child labours is likely to be considerable.

▶ **Health impact of mercury on vulnerable mine worker groups in vulnerable situations**

Women

- Female workers are at particularly high-risk during child-bearing years and pregnancy, when even low doses of mercury can elicit dramatic and irreversible effects.
- Women are more likely to have more adipose tissue and to store chemicals that bioaccumulate, including heavy metals like mercury.
- Female workers exposed to mercury may face severe consequences to their reproductive health, and exposure during pregnancy may result in spontaneous abortion, neurobehavioural consequences or birth defects.
- The fact that mercury can bioaccumulate means that occupational exposures even years before pregnancy can still negatively impact the developing foetus.

Child labourers

- The adverse impact of mercury exposure on children's health is unique due to their developing physiology, anatomy, metabolism, and health behaviours.
- Developing children are especially vulnerable and may have different susceptibilities during different life stages, especially during "critical windows of development" (Landrigan et al. 2004).
- Children may inhale larger doses of mercury vapour than adults, as their lungs have a greater surface area relative to their body weight and they breathe faster. In addition, mercury vapour is heavier than air and higher concentrations may accumulate at lower heights near a child's breathing zone (Besser 2009).
- Exposure to very high mercury levels can cause irreversible neurodevelopmental damage to brain function, including problems with attention span, language, visual-spatial skills, and coordination. Acrodynia (or 'pink disease'), characterized by red and painful extremities, insomnia, irritability and light sensitivity, has been reported in young children as a result of chronic mercury exposure (WHO 2021a).

Migrants

- Migrant workers may not speak the local language or dialect, making it difficult for them to understand chemical labels, safe handling procedures and training materials.
- Migrants and seasonal workers often work in the informal economy, making them more susceptible to unsafe work environments.
- The lack of regulation in informal workplaces leaves many workers at risk, due to an absence of information and education regarding health hazards, limited risk assessment and ineffective preventative control measures.

People with disabilities

- People with disabilities have been shown to have generally poorer health outcomes (WHO 2011) and disabled workers may also face unique risks depending on their particular disability, making them more vulnerable to mercury exposure and its effects.

Cyanide

Highly toxic sodium cyanide (NaCN) is used in mining to separate gold from ore. It is widely used in LSM, but is also increasingly used in ASGM, as it can recover more gold than mercury amalgamation (EPA 2017). Whilst the gold recovery rate for mercury is 20-50 per cent, cyanide has a rate of around 60 to 90 per cent (AGC 2020). International pressures to phase out mercury use have also contributed to this increase. Cyanidation processes are often out of reach for ASGM however, as they are generally costlier and require more knowledge and technical training (Veiga et al. 2009).

Workers may be at risk from direct exposure or from cyanide spills, which can contaminate water suppliers and agricultural lands. It is a fast-acting poison that prevents oxygen from being used by the cells, resulting in tissue hypoxia and death (Utembe et al. 2015). If cyanide is properly handled, risks to human health can be minimized, however inadequate OSH procedures in many ASGM put mine workers in danger. Workers may be exposed by inhaling hydrogen cyanide gas, especially when the pH of the cyanide solution is not maintained (AGC 2020). This is especially dangerous in enclosed poorly ventilated spaces. In addition, miners may be exposed via dermal contact, for example when working with bare feet in cyanidation ponds (AGC 2020). As for mercury, workers and their families may also be exposed to contaminated water and food sources.

Cyanide is sometimes used to capture residual gold by leaching ore and tailings to which mercury has been previously added. This is a worst practice under the Minamata Convention, as cyanide increases the environmental mobility of mercury (EPA 2017). The use of cyanide to process tailings is commonly practiced in a number of countries, including Brazil, China, Colombia, Ecuador, Mozambique, Nicaragua, Peru, the Philippines, Tanzania, Venezuela and Zimbabwe (IGF 2018).

Health impacts of cyanide exposure

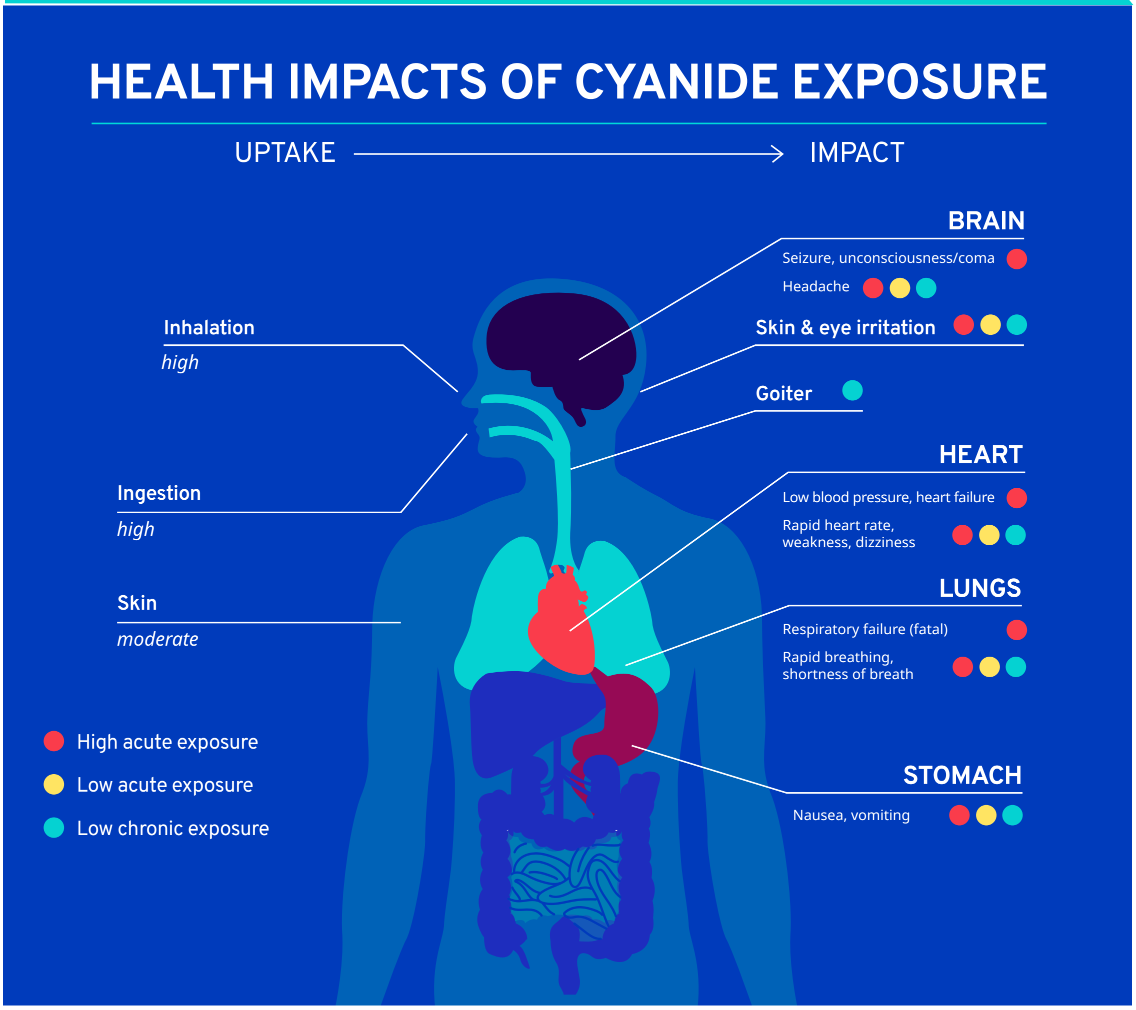
Cyanide is deadly when swallowed, even in minute doses. The inhalation of 120 mg/m^3 can cause life-threatening injuries and may lead to death after 30 to 60 minutes; exposure to over 300 mg/m^3 is immediately fatal (AGC 2020). Whilst the lungs and gastrointestinal system can absorb high amounts of cyanide, absorption through skin is moderate. Onset of signs and symptoms following exposure is rapid (PHE 2016).

At low exposure levels, most cyanide leaves the body within 24 hours without any long-term implications. Low dose acute exposure symptoms include dizziness, headache, nausea, vomiting, rapid breathing, rapid heart rate, restlessness, weakness, hypoxia, and skin and eye irritation. High dose acute exposures can additionally lead to seizures, loss of consciousness, respiratory failure and death (Figure 9).

Long-term exposure to low levels of cyanide can damage the central nervous system, causing intellectual deterioration, confusion, personality changes, memory deficits and Parkinsonism (PHE 2016). It may also impact the cardiovascular system (causing rapid heart rate), the respiratory system (causing breathing difficulties and chest pain) and enlarge the thyroid (AGC 2020).

Children show similar symptoms to adults, however smaller doses can be more harmful. Cyanide can also pass the placental barrier and impact the developing foetus, however limited evidence is available on reproductive and developmental toxicity.

▶ **Figure 9: Major health impacts of cyanide exposure (AGC 2020)**



▶ Cyanide use in ASGM in Burkina Faso (Knoblauch et al. 2020)

A cross-sectional epidemiological study of 279 individuals was carried out in three ASGM sites in Burkina Faso. Three exposure groups were included:

- **i.** miners using cyanide;
- **ii.** miners who did not use cyanide; and
- **iii.** ASGM community members not directly involved in mining.

Mean blood lactate levels (a proxy indicator for cyanide exposure) were significantly higher in miners using cyanide, compared to non-cyanide using miners and other community members not involved in mining activities. Additionally, loss of short-term memory was reported by participants associated with higher blood lactate levels.

Sulfuric Acid

Sulfuric acid is strong acid used in copper mining to leach copper oxide minerals. Other uses of sulfuric acid in mining include metal cleaning, explosives production, bauxite processing and metallurgy. It is also produced as a by-product in many kinds of mining, mixing with water and heavy metals to form acid mine drainage. Contact with sulfuric acid can cause irritation of the eyes, nose and throat, as well as burns, blindness and death. Long-term exposure can cause chronic inflammation of the respiratory tract (Hesperian Health Guide 2020).

Solvents

The term 'solvent' is generic and includes hundreds of different chemical compounds. Solvents are used to dissolve or dilute other substances and are used in mining to separate minerals from ore. They are volatile agents and occupational exposure generally occurs by inhalation of vapours, although dermal exposure may also occur. Blood absorption occurs quickly after exposure, with blood levels dependent on environmental factors, such as solvent concentration in the air, room ventilation and duration of exposure (Hurley and Taber 2015). Solvents may also be retained in organs with high lipid content, such as the brain, with potentially adverse health impacts.

Extremely limited data exists regarding the use of solvents in mining specifically and the prevalence of related health impacts. However, evidence from other industries can provide an indication of possible effects.

The impacts of solvent exposure are usually solvent-specific and should therefore be considered on an individual basis. Some solvents have been identified as carcinogenic to humans. Aside from cancer, the principal health effects most typically associated with organic solvent exposure include nervous system dysfunction, kidney and liver damage and skin lesions. Virtually all solvents can cause adverse effects to reproductive health. Specifically, they have been associated with sperm changes, infertility, cleft palates, miscarriage, newborn infection and childhood cancer (Rim 2017).

Acute health impacts include skin, eye and lung irritation, headache, nausea, dizziness and light-headedness (ILO 2004). Very high levels, for example in unventilated spaces, can lead to unconsciousness, seizures and even death (Dick 2006). Chronic exposure in the work environment can produce a range of adverse neurotoxic effects, including headache, fatigue, memory and concentration impairment, irritability, depression and personality changes (White and Proctor 1997). Commonly used solvents in mining include hydrocarbons that can cause skin irritation after prolonged exposure.

Chronic solvent induced encephalopathy (CSE) can occur after long-term exposure to solvents, for example, in chronically exposed workers. This syndrome is characterized by symptoms of fatigue, irritability and forgetfulness, as well as neurobehavioural deficits, such as decreased motor performance and information processing (Van Valen et al. 2012).

Silica dust

Silica, or silicon dioxide (SiO_2), is a natural compound of silicon and oxygen found in sand and many types of rocks. Occupational exposure to respirable crystalline silica (c-silica) occurs in many different types of mines. Copious amounts of silica dust is produced during mining processes such as rock drilling, mineral extraction, ore crushing and milling. The dust can contaminate other ore or materials being mined and pollute the mining environment, thus inadvertently exposing other workers. For example, substantial exposure to respirable c-silica occurs amongst coal miners in the central Appalachian coal mines in the United States, where thin seams of coal lie sandwiched between silica-rich sandstone. The prolonged inhalation of dust during drilling, mineral extraction, ore crushing and milling in the mining sector causes fine silica to be deposited in lungs.

Crystalline silica (c-silica) is classified by IARC as carcinogenic to humans (Group 1). According to IARC there is sufficient evidence that c-silica causes cancer of the lung (IARC 2012). Short-term exposure to respirable dust can cause irritation to the upper respiratory tract, whilst chronic exposure has been linked to silicosis, pulmonary tuberculous, obstructive airways disease and kidney disease (Ross and Murray 2004). Silicosis is irreversible and progressive and can substantially shorten the life span of an affected miner. Since the onset of symptoms is usually slow, silicosis often remains undetected and undiagnosed. Because silicosis affects the immune system, exposure to silica also increases the risk of lung infections, such as tuberculosis (OSHA n.d.)

Data on silica exposure in ASM is limited, however field observations suggest it is extensive, especially in hard rock mining (AGC 2020). A study in Tanzania found average concentrations of 0.19mg/m^3, in above ground operations, exceeding the NIOSH recommended exposure limit by four times (Gottesfeld et al. 2015). According to OSHA (2016), exposure to 0.05 mg/m^3 over a period of 45 years causes silicosis in 5 out of 100 people, whilst exposure to twice as much silica dust (0.1 mg/m^3) increases the risk to 30 in 100 people.

Silica dust on a miner's hands.

▶ **Silicosis prevalence in South Africa goldminers (Churchyard et al. 2004)**

A cross-sectional study of 520 migrant contract workers on a South African goldmine found silicosis prevalence to be between 18.3 to 19.9 per cent. Significant trends were found between silicosis prevalence and length of service, mean intensity of exposure and cumulative exposure. Importantly, the study found that workers developed silicosis while exposed to a quartz concentration below South Africa's recommended occupational exposure limit (OEL) of 0.1 mg/m^3.

Diesel particulate matter (DPM)

Underground miners may also be exposed to high levels of diesel particulate matter (DPM) from the use of diesel-powered mobile equipment. Most of the mines in the world use diesel-operated vehicles for transportation of workers, material, ore, waste rock, coal and for various other mining operations. Underground miners can be exposed to more than 100 times the environmental concentration of diesel exhaust and more than 10 times the level found in other workplaces (NIOSH n.d.). Diesel engines are a major contributor to elevated concentrations of carbon monoxide, carbon dioxide, oxides of nitrogen and hydrocarbons in underground mines. DPM exposure has been linked to cardiovascular dysfunction, eye and nose irritation, nausea, asthma and neurodegenerative disease (Donoghue 2004; Levesque et al. 2011). DPM is also classified as an IARC Group 2A probable human carcinogen and studies have indicated a positive relationship between lung cancer mortality and prolonged high DPM concentration exposure (Chang and Xu 2017).

Explosives

Explosives such as ammonium nitrate and fuel oil (ANFO) are used in mining operations, for example to blast tunnels. Detonating explosives releases toxic gases, primarily oxides of nitrogen and carbon monoxide. Nitric oxide and nitrogen dioxide are produced by large surface blasts in which the explosive does not detonate properly. Even in relatively small concentrations, nitrogen dioxide can produce harmful side effects in underground workers (NIOSH n.d.). Carbon monoxide is a particular problem in underground blasting, where the gas cannot dissipate to safe levels (NIOSH n.d.). Following a blast, workers must wait long enough to allow the fumes to dissipate, using a portable gas monitor to ensure that the air near the blast site is safe to breathe before proceeding (NIOSH n.d.). Mine workers may become ill or die if they remain in an area where toxic fumes levels are high. Unmixed ammonium nitrate can decompose explosively and has been responsible for several industrial disasters, including the 2020 Beirut explosion.

Case study: Chemical health hazards in LSM - Sukari Gold Mine, Egypt (Rabeiy et al. 2017)

The Sukari Gold Mine in the South of the Eastern Desert in Egypt is considered the largest and most modernized gold mine in the country. An occupational exposure and health risk assessment was carried out to measure hazardous substances present in the mine. Chemicals assessed included particulate matter (PM) and harmful gases, such as carbon monoxide, sulphur dioxide, nitrogen dioxide, hydrogen cyanide (HCN) and ammonia.

Measurements of chemical gases in the workplace showed that most gas concentrations were lower than permissible limits. The exception was HCN, where high levels with a value of 10 ppm were recorded in Carbon-in-Leach Tanks.

The study concluded that the modern mining and extraction methods applied in Sukari Gold Mine have reduced the severity of occupational exposure to physical and chemical hazards in workplaces. However, HCN levels were above permissible limits in some work areas.

Priority actions

This review demonstrates the need for prompt action to protect mine workers from the harmful effects of the many hazardous chemicals they may be exposed to daily. Actions to ensure worker protection and prevention efforts should be taken at the policy level and the workplace level, with a strong foundation of social dialogue throughout.

Policy level actions

Ratify and implement key ILO instruments

The following are key ILO conventions that can be implemented to protect mine workers from exposure to hazardous chemicals, through an integrated approach. The provisions outlined in the instruments allow countries to develop or adapt their own legislative and regulatory frameworks on the safe handling of chemicals in mines. Work in this subsector is also guided by the 1999 Conclusions of the ILO Tripartite Meeting on Social and Labour Issues in Small-scale Mines, which addressed safety and health, child labour and environmental issues in ASM.

Occupational Safety and Health Convention (No. 155) and Recommendation (No. 164), 1981, and its Protocol of 2002

The convention lays down fundamental objectives and defines the basic principles of a coherent national OSH policy. It covers workers in all branches of activity and is the most comprehensive of the current standards. The key provisions require Member States, in consultation with the most representative employers' and workers' organizations, to formulate, implement and periodically review a coherent national policy on OSH and the working environment, the aim being the prevention of occupational accidents and injuries by eliminating or minimizing the causes of hazards. As outlined in Article 16, employers are required to ensure that workplaces are safe, and chemical hazards under their control are without risk to health when appropriate measures of protection are taken. The convention is supplemented by Recommendation No. 164, which provides further details and additional practical guidance on several of the provisions in Convention No. 155. The Protocol of 2002 to Convention No. 155 calls for the establishment and the periodic review of requirements and procedures for the recording and notification of occupational accidents and diseases, and for the publication of related annual statistics.

Promotional Framework for Occupational Safety and Health Convention (No. 187) and Recommendation (No. 197), 2006

This convention aims to promote a preventive safety and health culture and to progressively achieve a safe and healthy working environment. It emphasizes the need to ensure that higher priority is given to OSH in national agendas and to foster political commitments in a tripartite context for the improvement of OSH. It is a promotional rather than prescriptive convention and is based on the application at the national level of a systems management approach to OSH. The convention also defines the elements and function of the national policy, the national system and the national programme, and discusses monitoring, evaluation and improvement of the national OSH system. Further operational details and mechanisms are provided in the Recommendation (No. 197).

The Occupational Safety and Health Convention, 1981 (No. 155) and the Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187) are now designated as fundamental Conventions. ILO member States, even if they have not ratified these two conventions, are now obliged to follow up on their commitment to tackling workplace hazards, including the protection of workers from chemical exposures in the mining sector.

Chemicals Convention (No. 170) and Recommendation (No. 177), 1990

The convention is general in scope and concerns all chemicals classified as hazardous that are used or produced in the workplace. It provides for a comprehensive national framework for the sound management of chemicals, including the formulation, implementation and periodic review of a coherent policy, in consultation with employers' and workers' organizations. An important feature of the convention are its provisions on chemical hazard communication designed to ensure that information on hazards, and related preventive and protective measures, flows from manufacturers and importers to the users. This includes requirements for the classification and labelling of chemicals, as well as regulating the production, handling, storage and transport of chemicals, the disposal and treatment of chemical wastes, the release of chemicals and the maintenance, repair and cleaning of equipment and containers for chemicals. At the workplace, the employer is required to ensure that all chemicals are identified, and that adequate information is available through labelling and safety data sheets (SDS), as well as to take all the necessary measures to eliminate, minimize or control exposure. Products that do not expose workers to hazardous chemicals under normal or reasonably foreseeable conditions of use, as well as organisms, are excluded from this requirement.

Safety and Health in Mines Convention (No. 176) and Recommendation (No. 183), 1995

This convention includes provisions for protecting the safety and health of workers in the mining sector, including risks posed by chemical hazards such as mercury. The main provision in convention No. 176 addressing chemicals is Article 9, which mandates that employers must inform workers of existing chemical hazards and all relevant preventative and protective measures for these hazards; take appropriate measures to eliminate or minimize those hazards; provide and maintain free protective equipment, clothing as necessary in the event that safety cannot otherwise be ensured; and ensure provision of first aid, transportation and appropriate access to medical facilities for workers suffering from injury or illness due to chemical hazards.

Occupational Health Services Convention (No. 161) and Recommendation (No. 171), 1985

The convention deals comprehensively with the provision of occupational health services and commits ratifying States to progressively develop occupational health services for all workers. The convention provides for the status, organization and conditions of operation for health services. The functions of these services are to include surveillance of the working environment and of workers' health, information, education, training and advice, and first aid, treatment and health programmes. Further guidance is given in the supplementing Recommendation No. 171. The ILO code of practice Technical and ethical guidelines for workers' health surveillance (1998) provides additional guidance on the subject. The ILO code of practice Protection of workers' personal data (1997) is also relevant in this area.

Labour Inspection Convention (No. 81) and Recommendation (No. 81) 1947, and its Protocol of 1995

The convention lays down the main rules governing the establishment, organization, means, powers and obligations, functions, and competence of the labour inspectorate as an enforcement institution for protecting workers and for promoting legislation adapted to the changing needs of the world of work. The establishment of a labour inspection system is obligatory for industrial establishments and optional for commercial establishments. Pursuant to the Protocol to Convention No. 81, Member States should extend the application of the convention to activities in the non-commercial services sector. Convention No. 81 is supplemented by Recommendation No. 81, which provides further details on the preventive duties of labour inspectorates and the collaboration of employers and workers in regard to safety and health and annual reporting on inspection.

Functions of a labour inspection system (Convention No. 81, Art. 3)

1. The functions of the system of labour inspection shall be:

a) to secure the enforcement of the legal provisions relating to conditions of work and the protection of workers while engaged in their work, such as provisions relating to hours, wages, safety, health and welfare, the employment of children and young persons, and other connected matters, in so far as such provisions are enforceable by labour inspectors;

b) to supply technical information and advice to employers and workers concerning the most effective means of complying with the legal provisions;

c) to bring to the notice of the competent authority defects or abuses not specifically covered by existing legal provisions.

Preventive duties of labour inspectorates are important, in line with Section I of Recommendation No. 81.

▶ Employment Injury Benefits Convention (No. 121) and Recommendation (No. 121), 1964

This convention notes that Member States shall prescribe a list of diseases, comprising at least the diseases enumerated in Schedule I (Diseases caused by mercury or its toxic compounds).

▶ Maternity Protection Convention (No. 183) and Recommendation (No. 191), 2000

The convention sets out that pregnant women should not be obliged to carry out work that is a significant risk to her health and safety or that of her child. It outlines the need for the elimination of any workplace risk, additional paid leave to avoid exposure if the risk cannot be eliminated, and the right to return to her job or an equivalent job as soon as it is safe for her to do so. The accompanying recommendation provides for specific risk assessment and management of risks concerning pregnant women, including exposure to chemical agents which represent a reproductive hazard.

▶ Occupational Cancer Convention (No. 139) and Recommendation (No. 147), 1974

The convention provides for the measures to be taken for the control and prevention of occupational hazards caused by carcinogenic substances and agents. Key provisions include periodically determining the carcinogenic substances and agents to which occupational exposure shall be prohibited or made subject to authorization or control, making every effort to have carcinogenic substances and agents to which workers may be exposed in the course of their work replaced by non-carcinogenic substances or agents, or by less harmful substances or agents, and reducing the number of workers exposed to carcinogenic substances or agents and the duration and degree of such exposure to the minimum.

▶ List of Occupational Diseases Recommendation, 2002 (No. 194)

The List of Occupational Diseases and the recording and Notification of Occupational Accidents and Diseases [List of Occupational Diseases Recommendation, 2002], includes diseases caused by mercury or it’s compounds (para.1.1.7). It represents the latest worldwide consensus on diseases which are internationally accepted as caused by work. It was designed to assist stakeholders in the identification and recognition of occupational diseases, including those caused by mercury.

▶ Worst Forms of Child Labour Convention, 1999 (No. 182)

Convention 182 outlines the 5 worst forms of labour that must be eradicated in order to step up the fight against child labour. This includes ‘Work which, by its very nature or the conditions in which it is undertaken, is likely to jeopardize the health, safety or morality of children.’ Due to the inherently dangerous nature of the work, no children should be involved in any work in the mining sector.

Implement a national OSH system for the sound management of chemicals

A strong national OSH system is critical for the effective implementation of policies and programmes on OSH and the sound management of hazardous chemicals in the workplace. Policies for the sound management of chemicals should always follow a systems approach, as outlined in the Convention No. 187 and its accompanying Recommendation No. 197.

Should include:	Should also include, where appropriate:
Laws and regulation, collective agreements where appropriate and any other relevant instruments on OSH pertaining to the sound management of chemicals.	A national tripartite advisory body, or bodies, addressing OSH issues related to chemicals.
	Information and advisory services on OSH measures regarding chemicals.
An authority or body, or authorities or bodies, responsible for OSH of chemicals, designated in accordance with national law and practice.	The provision of OSH training regarding the sound management of chemicals.
	Occupational health services for workers exposed to chemicals, in accordance with national law and practice.
Mechanisms for ensuring compliance with national laws and regulations regarding chemical management, including systems of inspection.	Research on OSH for chemicals exposures.
	A mechanism for the collection and analysis of data on occupational injuries and diseases related to chemical exposures, taking into account relevant ILO instruments.
Arrangements to promote, at the level of undertaking, cooperation between management, workers and their representatives, as an essential element of workplace-related prevention measures for the sound management of chemicals.	Provisions for collaboration with relevant insurance or social security schemes covering occupational injuries and diseases from chemical exposures.
	Support mechanisms for a progressive improvement of OSH conditions for enterprises using chemicals, including micro-enterprises, small and medium-sized enterprises and the informal economy.

▶ A partnership between the ILO and the United States Department of Labor (USDOL) in the Philippines (ILO 2021b)

A joint project between the ILO and USDOL is being carried out in the Philippines, with the aim of improving working conditions in a number of industries, including mining. Mining contributed US$4 billion to the country's GDP through exports in 2019, however gender inequality and low levels of labour compliance have been identified as major issues for the sector. Workers have limited rights to organize and engage in social dialogue, making them susceptible to serious labour violations, such as forced labour and child labour.

The four-year project on "Improving Workers' Rights in the Rural Sectors of the Indo-Pacific with a focus on Women ", aims to promote and strengthen compliance with labour laws, OSH and gender equality in rural sectors. The project is implemented as part of of the ILO's Safety + Health for All Flagship Programme to improve safety and health globally.

Minamata Convention for Mercury

The Minamata Convention, a global UN treaty to protect human health and the environment from the adverse effects of mercury, entered into force on 16th August 2017. It now has 128 signatories and 137 parties[1], who are legally bound to fulfil a range of mandatory measures. The Convention's core objective is "to protect human health and environment from anthropogenic emissions and releases of mercury and mercury compounds."

The main features of the Convention impacting mine workers are:

- The ban on new mercury mines and phase-out of existing ones, and controls on international trade in mercury (Article 3 – Mercury supply sources and trade)
- Controls on ASGM and guidelines for National Action Plans (NAPs) (Article 7 and Annex C – Artisanal and small-scale gold mining)
- Development and implementation of education and preventative programmes on occupational exposure to mercury (Article 16 – Health aspects)
- Other relevant articles include: Article 11 – Mercury wastes, Article 12 – Contaminated sites, Article 14 – Capacity building technical assistance and technology transfer, Article 17 – Information exchange and Article 18 – Public information, awareness and education.

Since the adoption of the Minamata Convention, relevant ILO activities in support of the implementation of the Convention have included promotion of ILO international instruments, project work at the country level, and production of global codes of practice and working documents.

1 As of 22 November 2023.

Figure 10: Content of the national action plan according to the Minamata Convention (Source: WHO 2021b)

- Strategies to eliminate worst practice and promote mercury-free methods
- Steps to facilitate the formalization or regulation
- Baseline estimates of the quantities of mercury used and the practices employed
- Strategies for managing trade and preventing the diversion of mercury
- Strategies for providing information to ASGM affected communities
- A public health strategy on the exposure of miners and their communities to mercury
- Strategies to prevent the exposure of vulnerable populations
- FAIRTRADE
  Strategies for mercury-free ASGM and market-based mechanisms or marketing tools

Countries that have ratified the Minamata Convention are obliged to develop a NAP, which describes its approach to reduce, and if possible, eliminate, the use of mercury in ASGM (Figure 10). The ILO advises that NAPs should align with ILO Decent Work Country Programmes (DWCPs), the main vehicle for delivery of ILO support to countries. DWCPs set forth the priorities of the ILO in a specific country, with the aim to promote decent work as a key component of national development strategies, as well as organizing ILO knowledge, instruments, advocacy and cooperation to advance the Decent Work Agenda. In addition, effective multi-sectoral collaboration is needed for NAPs at both national and local levels, especially with labour sector stakeholders. Many countries have started developing a NAP, including collecting baseline data regarding ASGM activity in their regions (UNEP 2018). The ILO recommends the integration of OSH into the public health strategy of the NAP, as well as identifying strategies to protect vulnerable populations, such as child labourers.

▶ ILO conventions and the Minamata Convention

Synergies exist between the Minamata Convention and the ILO conventions and OSH instruments. Mercury is covered by the general OSH and chemicals conventions (Nos. 170, 174 and 155), which cover all chemical risks. The obligations in the Minamata Convention with the most overlap with ILO conventions is Article 5 on manufacturing processes involving mercury. As mercury is a hazardous chemical, it is covered by the general provisions in ILO Conventions No. 170 and 174, which protect workers against exposure to mercury in all manufacturing processes involving this substance.

▶ ILO Safety and Health in Mines Convention, 1995 (No. 176) and the Minamata Convention

A highlight of Convention No. 176 is its synergies with the Minamata Convention on Mercury. Use of mercury in mining, especially in gold mining, continues to constitute a major health hazard. While Convention No. 176 does not mention mercury directly, the open provisions on chemicals in Article 9 cover this substance and therefore mandate the elimination or at least minimization of hazards relating to mercury as well as other hazardous chemicals used in gold mining. Mercury in mining is also addressed by the Minamata Convention, which contains provisions on the dangers relating to ASGM. Convention No. 176 and the Minamata Convention therefore complement each other, as Convention No. 176 closes the gaps when it comes to chemical exposures, for example regarding other hazardous chemicals used in mines, such as cyanide and solvents.

Other policy level actions:

▶ Develop, update and harmonize evidence-based occupational exposure limits (OELs) for chemicals used in mines

Occupational exposure limits (OELs) are regulatory values which indicate levels of exposure that are considered safe for a chemical substance in a workplace. Unfortunately, OELs do not exist for many chemicals and those that do exist are often outdated. There is also a lack of harmonized data between different countries and safety bodies. Whilst databases of OELs provide valuable information on numerous chemical exposures, keeping these lists updated and relevant is a huge task. Suggested actions include:

- Create a priority system for OELs, to focus on those that do not exist or need to be updated.
- Ensure that OELs are easily understandable and accessible.
- Consider all potential health hazards, rather than only acknowledging single health effects.

- Develop an approach covering all chemicals in the workplace, rather than focusing on individual chemicals only.
- Produce and implement harmonized international guidelines for OELs.
- Promote OELs on an international level with policy makers and industry representatives to ensure that OELs are enforced.
- Update key OELs on a systematic basis to reflect advancements in science and technology.

OELs for mercury

Some workplace exposure limits for mercury include:

- ACGIH: The threshold limit value (TLV) is 0.025 mg/m^3 as an 8-hour time-weighted average (TWA).
- EU-OEL: 0.02 mg/m^3 as TWA.
- OSHA: Permissible exposure limit (PEL) for mercury is a ceiling limit of 0.1 mg/m^3 as TWA.
- NIOSH: Exposures to mercury vapour should be limited to an average of 0.05 mg/m^3 over a 10-hour workday, in addition to a ceiling limit of 0.1 mg/m^3.

Mild subclinical signs of central nervous system toxicity can be seen in workers exposed to an elemental mercury level in the air of 20 µg/m^3 or more for several years (WHO 2021a). There may therefore be a case for more stringent OELs than currently exist.

Implement the Globally Harmonized System of Classification and Labelling of Chemicals (GHS)

The GHS is an internationally agreed upon system to standardize hazard information of chemicals through labels and SDS. Correct classification and labelling, as well as comprehensive worker training, can help improve OSH and workplace safety systems in mines. Appropriate handling, use and storage of hazardous substances can in turn contribute to preventing hazardous exposures, as well as major industrial accidents. Social partners have supported global implementation of the GHS as a way to share safety and health information to prevent worker exposures to hazardous substances.

Gather better data on ASM

Due to its largely informal nature, data on ASM is lacking in all areas. Even for ASGM, the total disease burden is likely undercounted due to poor data availability and quality. National assessments of chemical usage and disposal in mining should be conducted. This will allow countries to develop an effective and targeted response to dealing with this growing concern. Critically, 60 per cent of ASM countries do not have published data on female participation in the sector, despite women making up significant portions of the ASM workforce (Delve 2020).

Mainstream gender considerations into OSH policy and practice

Inclusive and gender-responsive OSH policies should be developed. The ILO Maternity Protection Convention, 2000 (No. 183) and accompanying Recommendation No. 191 set out that pregnant women should not be obliged to carry out work that is a risk to her or her child and provides for specific risk assessment concerning pregnant women, including chemicals such as mercury, which represent a reproductive hazard. In addition, the Worst Forms of Child Labour Convention, 1999 (No. 182), states that the worst forms of child labour includes work which, by its nature or the circumstances in which it is carried out, is likely to harm the health, safety or morals of children.

Furthermore, the ILO has developed Guidelines for Gender Mainstreaming in Occupational Safety and Health to assist policy-makers and practitioners in taking a gender-sensitive approach for the development and implementation of OSH policy and practice. In taking a gender sensitive approach, one recognizes that because of different jobs that men and women participate in, and the different societal roles, expectations and responsibilities they have, they may face unique chemical exposure scenarios, thus requiring appropriately designed control measures. This approach improves the understanding that gender-based division of labour, biological differences, employment patterns, social roles and structures all contribute to gender-specific patterns of hazardous exposures.

▶ Case study:
Moyo Gems - An ethical gemstone collaboration in Tanzania (Delve 2020)

80 per cent of all coloured gemstones come from informal ASM in remote areas of the world. The Moyo Gem initiative works mainly with women miners, empowering them to work safely and mine better. Miners also receive free safety and health training. Begun in 2019, the collaboration supports artisanal gemstone miners of the Umba Valley in North-East Tanzania to assure fully traceable rubies, sapphires, tourmalines, and garnets from mine to market. It aims to increase skill level, income earnings and investment potential of female ASM miners, as outlined by SDG targets 8.5 and 8.10.

▶ Follow a 'toxics use reduction' approach

- A 'toxics use reduction' approach is needed to prioritize the identification and use of safer alternatives to hazardous chemicals, such as mercury and cyanide.
- In line with control measures outlined in the Hierarchy of Controls, finding economically viable alternatives to the most toxic chemicals should be considered a priority, over other workplace protective measures.
- A 'one size fits all' approach will not be effective considering the many different populations and mining sectors.

▶ Links between large and small mines (ILO 1999; DFID 2005)

- With the assistance of governments, employers and workers' organizations in the mining industry, there is a potential for ASM to move towards formalization to reduce poverty, increase foreign exchange earnings and prevent rural migration and environmental destruction. Proper legal and social support can turn ASM into a valuable source of economic and sustainable development, particularly in rural areas.
- The technical information, best practices, OSH data and information that exist throughout the mining industry should be made available by governments, and where appropriate by employers and workers' organizations, to those involved in ASM.
- Employers' and worker's organizations, particularly at the local level, can provide assistance to small-scale mines to improve their operations and social conditions at the mine sites and in the community. Donor assistance to mobilize efforts on behalf of ASM should be sought. Upon request, the ILO can supervize and coordinate pilot projects that include employers and workers' organizations to deal with problems in the sector.
- Governments, employers' and workers' organizations could explore how large mines and their workers could act as mentors to ASMs.

Workplace level actions

Although the substitution of certain chemicals, such as mercury, is a priority, workplace prevention efforts should also be implemented as complementary actions. Targeted strategies are needed at both the national and workplace levels, particularly in LMICs and in the informal economy.

Specific guidance on the control of hazardous substances and chemicals in mining can be found in the following two ILO codes of practice on mining:

- Safety and health in underground coalmines (2009).
- Safety and health in opencast mines (2018).

Implement a workplace programme for the sound management of chemicals

The following components could be used as a general blueprint for the sound management of chemicals in the workplace. Effective risk assessment is also essential and is included in a workplace strategy. As always, SDS national guidelines should be considered in the first instance.

Elements of the programme	Components included
General obligations, responsibilities and duties	Role of the competent authority Responsibilities and duties of employers, workers, and suppliers Rights of workers
Classification and labelling following the GHS	Criteria for classification of hazards Methods for classification Type of labelling on containers of hazardous chemicals
Chemical safety data sheets (SDS)	Provision of information and training Content of SDS
Operational control measures	Assessment of control needs and elimination of hazards Control measures for: health hazards; flammable, dangerously reactive or explosive chemicals; disposal and treatment of chemicals
Design and installation	Enclosed systems where feasible Separate areas for hazardous processes to limit exposures Practices and equipment that minimize releases Local exhaust ventilation and general ventilation
Work systems and practices	Administrative controls Cleaning and maintenance of control equipment Provision of safe storage for hazardous chemicals
Personal protection	Personal protective equipment (PPE) Welfare facilities and personal hygiene Practices to maintain equipment and clothing as necessary Training on personal protection

Information and training	Workers should have training on all workplace control measures. They should be provided information (labels and SDS), and be trained how to handle chemicals safely, what to do in an emergency, and how to obtain additional information. Some hazardous substances, for example respirable crystalline silica and DPM, do not have SDS.
Maintenance of engineering controls	Practices and procedures to keep engineering controls in good working order
Exposure monitoring	Measuring methods Monitoring strategy Recordkeeping Interpretation and application of data
Medical and health surveillance	Medical exams as necessary Recordkeeping Use of results to evaluate programme Paid time off for affected workers, including paid sick leave Employment protection for those harmed by chemicals Transfer to alternative employment for pregnant/breast feeding workers
Emergency procedures and first aid	Planning should be done to anticipate possible emergencies, and have procedures to deal with them First aid should be available on-site
Investigation, recording and reporting of accidents, occupational diseases and other incidents	All incidents, accidents and diseases should be investigated to determine why they occurred, what failed in the workplace or in the emergency plan The accident and dangerous incident book should be reviewed regularly to identify risky jobs and processes and to revise risk assessments Authorities should be notified as required by national laws

Health surveillance of high exposure industries

Regular health surveillance and biomonitoring of mine workers, together with recognition of OELs, help in the early detection of chemical exposure and related biological effects. They also provide information on whether current risk control measures in mines are effective or if further action is required. Challenges exist however with regard to monitoring and surveillance, as many countries do not have the technical capacity and laboratory capacity to establish baseline conditions and subsequently to conduct monitoring (WHO 2019). Human biomonitoring is seen as an effective approach to identify and monitor vulnerable populations, but there is a need for assistance to implement it in many countries.

Case study:
Coal Workers' Health Surveillance Program in the USA

The NIOSH Coal Workers' Health Surveillance Program (CWHSP) was established by the Federal Coal Mine Health and Safety Act of 1969 (amended in 1977). The programme studies the causes and effects of respiratory diseases related to coal mine dust exposure, including pneumoconiosis, silicosis and chronic obstructive pulmonary disease (COPD). Black lung screenings are provided by the NIOSH staff who travel the U.S. in state-of-the-art mobile testing units. Screenings include work history and respiratory health questionnaires, chest x-rays, spirometry and blood pressure monitoring.

Training of workers, employers and labour inspectors is key for ensuring OSH measures are carried out effectively

According to Article 19 of Convention No.155, workers must be given adequate information and receive appropriate training on OSH measures. Repeated training for employees, supervisors, occupational medicine physicians and safety staff is of particular importance (WHO 2016). The ILO also emphasizes the value of labour inspector training, to develop competences of labour inspectorates and enhance inspection effectiveness. This is essential for enforcing legal provisions relating to work conditions and the protection of workers and for identifying defects of existing legal provisions.

Implement an adapted workplace level risk assessment

A workplace risk assessment is one of the key tools for protecting occupational safety and health conditions for those working in mines. It plays an important role in protecting miners from chemical hazards, as well as complying with the laws on chemical safety in many countries. A risk assessment is carried out to categorize hazards, evaluate risks, and identify and implement appropriate control measures. It should take into account exposures during all stages of the mining process, including exploration, extraction of metals and dealing with chemical wastes.

The risk assessment should comprise the following five steps[2]:

Step 1: Identify the hazards

The first step is to identify what chemicals are present in the mine, for example cyanide or solvents, and their specific risks to worker safety and health. They should be classified as to their health, physical and environmental hazards, through appropriate labelling and SDS. Workers may face a range of exposure pathways, including inhalation, ingestion or dermal contact, depending on the chemicals used and specific tasks performed.

Step 2: Identify who might be harmed and how

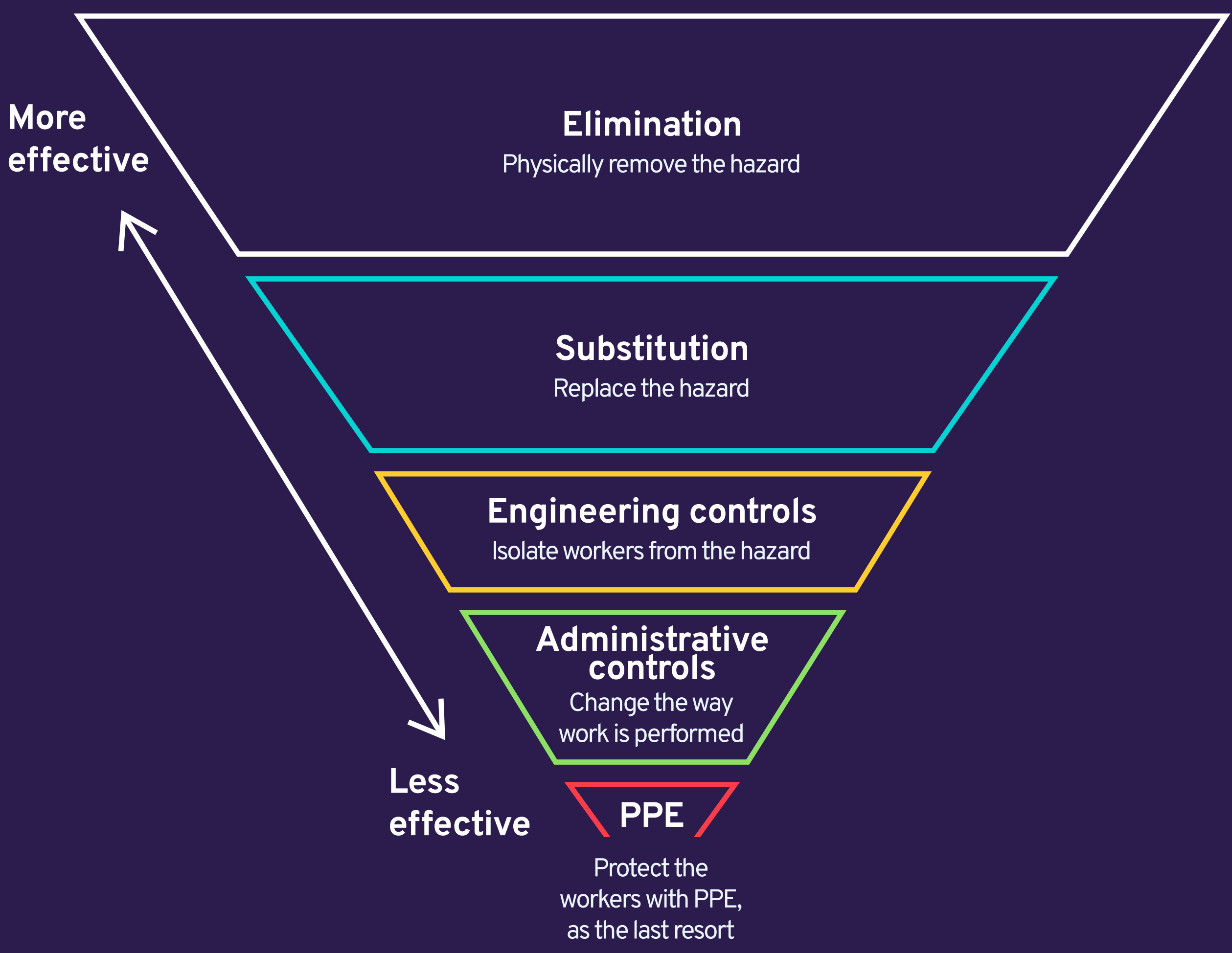
Once the sources of potential exposure have been identified, the risk assessment should identify which workers are at particular risk of hazardous exposures, and also potential safety and health impacts. Some workers, for example, contractors and maintenance workers, may not always be present in the workplace, however may still be exposed to some degree. Workers in vulnerable situations are potentially at greater risk, for example pregnant and nursing women, migrant workers and workers with a disability. For instance, even low levels of mercury can cause dramatic and irreversible effects on pregnant women and their foetuses.

2 See A 5 Step Guide for employers, workers and their representatives on conducting workplace risk assessments. ILO 2014.

Step 3: Evaluate the risk – Identify and decide on the safety and health risk control measures

Once the hazards have been identified, classified, communicated, and their risk has been assessed, the third step is to use this information to design an appropriate preventive and protective programme for the mine using the Hierarchy of Controls (Figure 11). There are five categories in the Hierarchy: Elimination, Substitution, Engineering controls, Administrative controls and Personal protective equipment (PPE), with Elimination and Substitution considered priority actions where possible. In a mine, this may involve finding a new process which means that chemicals such as mercury and cyanide are not needed, or substituting these chemicals for less hazardous ones. Control measures at the top of the Hierarchy provide collective protection, which is preferable to the personal protective measures at the bottom. However, in many cases, a combination of various control measures throughout the hierarchy should be implemented to ensure optimum protection. An example of the Hierarchy of Controls when applied to mercury use in ASGM is shown in Figure 12.

Figure 11: The Hierarchy of Controls



▶ Figure 12: Example of the Hierarchy of Controls for mercury use in ASGM

More effective	**Elimination**	Physically remove the chemical	e.g. Eliminate the use of mercury and use a zero-mercury approach instead, for example, panning, sluicing or spiral concentrators
↑	**Substitution**	Replace the chemical	e.g. Use an alternative chemical for the process, one that is less hazardous
	Engineering Controls	Isolate workers from the chemical	e.g. Use fume hoods to remove the mercury fumes
↓	**Administrative Controls**	Change the way work is performed	e.g. Adjust work tasks or schedules to limit the time workers are exposed to mercury, ensure there is adequate ventilation and safely store mercury, work clothes and equipment at work only. Workers should be trained to ensure they are aware of all chemical hazards and their associated risks, as well as safe work systems.
Less effective	**Personal Protective Equipment (PPE)**	Protect the worker with PPE	e.g. Workers should wear appropriate PPE, for example gloves, overalls, masks with filters, and safety glasses, as deemed relevant by risk assessment

▶ Step 4: Record who is responsible for implementing which control measure, and the timeframe

Once control measures have been decided, action should be taken to ensure they are implemented effectively. It is good practice to allocate responsibility of this to named individuals, as well as deciding on an appropriate timeline for their implementation. If resources are limited, control measures should be prioritized based on degree of risk. If necessary, a few low-cost or easy improvements can be installed in the short-term, until more reliable controls can be put in place. A plan of action may also include worker training and regular checks to ensure the measures are still in place.

▶ Step 5: Record the findings, monitor and review the risk assessment, and update when necessary

Risk assessment findings should be recorded and made available to supervisors, workers and labour inspectors. Arrangements will be needed to monitor the effectiveness of the control measures and one way of doing this is through mine inspections. The risk assessment should be regularly reviewed and updated, as there may be changes to the types and quantities of chemicals used in the mine. This may result in new potential exposure pathways that put workers' safety and health at increased risk. In addition, the control measures may not adequately address risks and further, more stringent measures may be needed.

Phasing out mercury use in ASGM

Multiple programmes are in place to help miners shift to mercury-free mining processes, but the challenges are vast (UNEP 2017). Whilst national and international initiatives seek to reduce mercury use in ASGM and to improve the safety and health of workers in the sector, the extent and informal nature of ASGM activities make implementation challenging.

UNEP has recommended the cessation of several common practices in ASGM, including WOA, open burning of amalgam without vapour capture systems or retorts, and reprocessing of mercury-contaminated tailings with cyanide. For artisanal workers who practice amalgamation, the burning of amalgam and gold sponge should no longer be done in the absence of PPE. Alternatives, such as "gravity only" separation, direct smelting and chemical leaching in keeping with good safety and health practices could be employed in the ASGM industry to reduce or eliminate mercury exposure and emissions.

A two-step approach is recommended

Whilst using completely mercury-free processing and refining may seem ideal, reducing mercury use may be a more realistic first step. This can help pave the way for mercury-free practices to be integrated into processes over the course of time.

Assess the potential for the formalization of ASGM activities

By supporting the transition from informal to formal ASGM in line with the ILO Transition from the Informal to the Formal Economy Recommendation, 2015 (No. 204), it should in principle become easier to identify, reach out to and provide ASGM mining operators with the knowledge and assistance needed to apply mercury-free processes and to improve working conditions and safety and health at work.

Nonetheless, it has become increasingly clear that the transition to the formal economy should be managed in ways that address specific risks as well as vulnerabilities of women in the sector. Women, for instance, will not be able to benefit from formalization in countries where they are prohibited from owning land or mineral rights. Hence, the transition to a formal mining economy should be accompanied by complementary and supportive policies for women and other marginalized groups – be it land rights, education and fundamental principles and rights at work – to ensure that formalization brings about equal opportunities and contributes to the advancement of decent work for all.

Worker training and awareness raising

Miners and other ASGM workers often have limited knowledge of the harmful health impacts of mercury exposure. Awareness raising through health promotion campaigns is essential for those working with mercury. Miners should be educated about the dangers of mercury vapour, for example released during WOA methods. Various existing training tools could be used or adapted to address the specific concerns of the ASGM sector, including WISE, WISH, SCORE and WIND.

Social dialogue

Promote social dialogue at all levels: towards effective ratification and implementation of International Labour Standards

Social dialogue is defined by the ILO to include all types of negotiation, consultation or simply exchange of information between, or among, representatives of governments, employers and workers, on issues of common interest relating to economic and social policy. It can exist as a tripartite process, with the government as an official party to the dialogue or it may consist of bipartite relations only between labour and management (or trade unions and employers' organizations), with or without direct government involvement. Social dialogue processes can be informal or institutionalized, and often it is a combination of the two. It can take place at the national, regional or at enterprise level. It can be inter-professional, sectoral or a combination of these. The main goal of social dialogue itself is to promote consensus building and democratic involvement among the main stakeholders in the world of work. Successful social dialogue structures and processes have the potential to resolve important economic and social issues, encourage good governance, advance social and industrial peace and stability and boost economic progress.

If laws and regulations are essential in determining the legal framework regulating the administration of national OSH infrastructures, the application of laws and regulations within the workplace rests to a large extent with employers, workers and the organizations representing them. Often, the subject of OSH, including all aspects of chemical safety at work, has been the starting point for developing wider bipartite dialogue. Both employers and workers, and particularly employers' and workers' organizations, give OSH an important place in their collaborative or separate actions. A joint OSH committee is a workplace bipartite body, which is set up to enable workers and employers to engage in social dialogue and work together in a collaborative and coordinated way, to address OSH issues in the workplace. They are composed of an equal number of workers' and employers' representatives, with legislation in some countries also requiring an OSH practitioner as a member. Collective bargaining is another way to engage on OSH at the workplace. The inclusion of the subject of OSH has long been a standard feature of collective bargaining agreements. Although the legal basis for the application of collective bargaining may differ significantly from country to country, the legislation of most industrialized and developing countries include a system for regulating collective bargaining.

The promotion of OSH and improvement of working conditions has certainly benefited greatly from such dialogue. Participation of employers and workers is emphasized under OSH instruments through express provisions on consultation and co-operation. States are required to consult with employers, workers and their representatives on the National Policy and Action at the National Level under Convention No. 155 (Articles 4 and 8, respectively). In establishing a body for co-ordination under Article 15 of Convention No. 155, States are also required to consult with employers, workers and their representatives. In addition, this principle is embedded in the Chemicals Convention, 1990 (No. 170), which requires the formulation, implementation and review of a coherent policy on safety in the use of chemicals at work to be undertaken on a tripartite basis, as well as requiring the cooperation between employers and workers with respect to safety in the use of chemicals at work.

The ratification and implementation of the Safety and Health in Mines Convention, 1995 (No. 176) is an important tool towards promotion of social dialogue in the mining industry. It was adopted specially to foment safety and health in mines for all workers and provides a solid framework to build a workplace safety culture.

To support sound social dialogue practices, systems for coordination and cooperation between the different authorities and bodies involved in the administration of the national OSH system are necessary to ensure coherence of action at all levels and to facilitate the flow of and access to information. The assignment of this function to a central body is an effective way to enhance the performance of such systems. Mechanisms for the consultation of organizations of employers and workers as well as other stakeholders as appropriate and their participation in policy and legislation development and review are also needed in order to take their views and concerns into account and ensure their support in implementation.

In this context, the Minamata Convention is one of the available instruments that promotes coordination, cooperation and consultation among different actors at the global level. The Minamata Convention anticipates that "coordinated implementation of the obligations of the Convention will lead to an overall reduction of mercury levels in the environment over time." What is clear is that the Convention requires multisectoral coordination and action. Given that mercury is used in numerous countries around the world and in many different industries, cooperation and collaboration at global, regional and national level will be key to achieving Convention objectives (WHO 2016b). In conclusion, implementation of the Minamata Convection at all levels goes hand in hand with ILO instruments on OSH, particularly Convention No. 170. Social dialogue will be an essential part of this global collaboration.

Enhance sound governance frameworks

The sound management of chemicals requires effective governance through transparency and accountability among the world of work stakeholders and specifically governments, employers' organizations and workers' organizations. Making full use of social dialogue is important to improve legislation and its implementation. The active participation of employers' and workers' organizations is essential for the development of national policies and programmes for the management of chemicals as well as its governance.

Employers have a duty to take preventive and protective measures, through assessment and control of the risks at work, including to those related to chemical exposures. They also can promote sound governance frameworks at the national and workplace levels. Workers have a duty to cooperate with their employers with respect to OSH and to comply with OSH responsibilities set out by the employers. Workers and their representatives should be involved at all levels in formulating, supervising and implementing prevention policies and workplace programmes. They have a right to be protected from workplace risks and to take an active role in governance both at the national and workplace level.

Policy makers, managers, supervisors, OSH professionals, and workers all have important roles to play, through effective social dialogue and participation in risk-management systems as well as the promotion of sound governance frameworks at all levels.

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