Artisanal and small-scale gold mining and health

TECHNICAL PAPER #1: ENVIRONMENTAL AND OCCUPATIONAL HEALTH HAZARDS ASSOCIATED WITH ARTISANAL AND SMALL-SCALE GOLD MINING

World Health Organization

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Contents

Foreword

Millions of people in the developing world depend on artisanal and small-scale gold mining (ASGM) for their livelihoods. This wealth, however, can come at a price.

ASGM has many associated environmental and occupational health issues, particularly when practiced informally or with limited technical and material resources. The health and well-being of miners, their family members as well as nearby communities is often adversely affected.

The Minamata Convention on Mercury, adopted in October 2013, has provided an important opportunity to catalyze global, regional and national intersectoral action needed to promote and protect the health and well-being of populations that depend on ASGM.

In recognition of its associated human health and environmental impacts, in particular resulting from the use of mercury in the ASGM process, the Convention obligates Parties, as applicable, to develop public health strategies on the exposure to mercury of ASGM workers and their communities. Such strategies must include the gathering of health data, training for health-care workers and awareness-raising through health facilities.

The present document is part of a WHO technical series on ASGM and health developed in response to World Health Assembly Resolution 67.11. It seeks to inform ministries of public health of roles they can play in supporting the implementation of ASGM related provisions of the Minamata Convention on Mercury.

Given the significance of occupational health issues in this context, this effort is also aligned with actions called for under World Health Assembly Resolution 60.26 and in the Global Plan of Action for Workers' Health (2008-2017), in particular actions focused on promoting and protecting health at the workplace and in hazardous working environments.

Health-care providers have a key part to play in responding to ASGM. However, in order to play this part, they need to be mobilized and adequately trained. It is in this spirit that this document has been put forward.

Dr Maria Neira

Director, Department of Public Health, Environmental and Social Determinants of Health

World Health Organization

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Acronyms and abbreviations

AGC	Artisanal Gold Council
ASGM	Artisanal and small-scale gold mining
CASM	Communities and Artisanal and Small-Scale Mining initiative
ILO	International Labour Organization
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
WHA	World Health Assembly
WHO	World Health Organization

Sponge gold: the output of the burning step in ASGM when amalgam is heated to separate mercury from the gold.

1 INTRODUCTION

1.1 SCOPE AND PURPOSE

An early version of this report served as a background document for a WHO technical consultation on artisanal and small-scale gold mining and health, which took place on 1-2 October 2014 in Geneva, Switzerland. The overarching goals of this meeting were to:

a) bring together world experts in order to take stock of current developments in the field.

b) solicit expert input in order to further develop WHO guidance to support the articulation of public health strategies on ASGM and training materials for building the capacity of health-care providers to identify and address environmental and occupational health issues associated with ASGM.

The current report provides a summary of the literature review that was carried out to support the development of the WHO guidance referred to above. It covers the environmental and occupational health hazards and adverse health outcomes associated with ASGM. Issues and special considerations for women and children are also explored.

The report also examines training programmes, toolkits and guides that can be used by, or developed into a curriculum on occupational and environmental hazards associated with ASGM for a health-care audience.

This report is intended primarily for health actors such as health-care providers working in areas where there are ASGM activities, as well as those regulatory authorities likely to play a role in developing the national or sub-national strategies or policies that address the health and well-being of ASGM miners and their communities.

Sections 1, 2, 3 and 4 give an overview of artisanal and small-scale gold mining, the steps and processes involved and some basic characteristics of workers and populations engaged in this activity. A detailed overview of ASGM-related health hazards is also provided together with a description of ways in which ASGM has an impact on the environment and on environmental determinants of health.

Sections 5 and 6 describe materials available to support training and awareness-raising activities among health-care providers, and concludes with a summary of the state of knowledge on this topic and gaps to be filled.

1.2 LINKAGES WITH THE MINAMATA CONVENTION ON MERCURY

The overarching objective of the Minamata Convention on Mercury (Article 1) is "to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds".

The Convention includes a range of measures to meet this objective, including controls on emissions and releases of mercury to the environment from industrial sources and phasing out or phasing down certain mercury-added products or product components.

The Convention includes an Article dedicated to health aspects (Article 16), which specifically calls for the development and implementation of strategies and programmes to identify and protect populations at risk from exposure to mercury and mercury compounds, including through the adoption of science-based health guidelines, health promotion and health education activities. This Article also calls for the promotion of preventive and curative services for populations affected by exposure to mercury and for the strengthening of health sector capacity to address mercury-related health issues.

In addition to Article 16, the implementation of other Articles will require contributions from the health sector. Health ministries will need to be involved in developing public health strategies as part of the national action plan to reduce the health impacts of mercury use in ASGM (required under Article 7) as well as in assessing contaminated sites for risks to health (Article 12). Article 17 on information exchange specifically mentions information on health impacts associated with exposure to mercury.

Article 18 on public information, awareness and education specifically mentions human health, while Article 19 (Research, development and monitoring) calls for education, training and public awareness related to the effects of exposure to mercury and mercury compounds on human health and the environment.

The content of this report relates specifically to responsibilities of the health sector under Article 7. Under this Article, Parties that determine that ASGM and processing in their territories are "more than insignificant" are required to develop a national action plan that includes a public health strategy on the exposure to mercury of artisanal and small-scale gold mining workers and their communities. Convention Parties are expected to gather health data, train health-care workers and raise awareness through health facilities as part of such a public health strategy (United Nations Environment Programme, 2014). Such strategies will also serve to implement a further requirement of Article 7 to include, in national action plans, strategies to prevent the exposure of vulnerable populations, particularly children and women of child-bearing age, especially pregnant women, to mercury used in ASGM.

The present report provides an overview of exposure to mercury in ASGM and the related effects on health. However, as the health and well-being of ASGM communities are affected by numerous other environmental and occupational health hazards, a wider public health approach and framing of the issues is also provided.

1.3 LITERATURE REVIEW: METHODOLOGY AND APPROACH

A structured approach was developed to identify and evaluate materials for review. Peer-reviewed and "grey" literature, in the form of reports from (inter-) governmental websites, research institutions and organizations carrying out research on ASGM and on artisanal and small-scale mining more broadly, were reviewed as part of this report. Additionally, medical texts were consulted in order to elaborate on the health hazards described in the first part of this report. Searches for peer-reviewed journal articles were conducted using the United States National Library of Medicine online database (PubMed). Google and the Google Scholar search engines were used for keyword, organization and research institute searches.

Keywords and phrases: artisanal and small-scale mining, artisanal and small-scale gold mining, ASGM, women and small-scale mining, children and mining, artisanal mining health, miner health assessments, artisanal mining education, artisanal mining training and resources, mercury gold, mercury and small-scale mining, mercury substitution, mining and cyanide.

Inclusion criteria: documents that described artisanal and small-scale mining and ASGM processes, male, female and child mining populations, mining communities, health and environmental hazards, training and educational materials for health-care providers and mine workers were included.

Exclusion criteria: materials on health and environmental hazards related to large-scale mining and content or presentations that were not properly cited were excluded.

Additional points to bear in mind with respect to the approach taken for the literature review are:

- ASGM has characteristics in common with other forms of artisanal and small-scale mining, particularly as regards work processes. Both will be referred to throughout this report;
- considerable information, in particular that related to artisanal and small-scale mining and ASGM work processes and workforces, was found in "grey literature" publications, generally in a case study format. Although health and environmental hazards affect miners and surrounding populations, peer-reviewed, published literature that addresses these issues from a health-care perspective is almost non-existent.

2 A BRIEF OVERVIEW OF ARTISANAL AND SMALL-SCALE MINING

Artisanal and small-scale mining involves a complex interplay of social, economic, technological, environmental and health factors that can vary considerably across local and national contexts. This complexity makes it difficult to establish uniform definitions. Artisanal and small-scale gold mining is defined in the Minamata Convention on Mercury as "gold mining conducted by individual miners or small enterprises with limited capital investment and production" (United Nations Environment Programme, 2014). The International Labour Organization describes artisanal and small-scale mining as "…labour intensive, with mechanization being at a low level and basic" (Jennings, 1999). Building on this description, the World Bank's Communities, Artisanal and Small-Scale Mining (CASM) initiative elaborates on the economic and social effects of artisanal and small-scale mining work as "… largely a poverty driven activity, typically practiced in the poorest and most remote rural areas of a country by a largely itinerant, poorly educated populace with little other employment alternatives" (World Bank, 2013). Most definitions of artisanal and small-scale mining share the following characteristics: an informal work sector, limited use of mechanical tools, labour-intensive work, low capital and productivity, deposit exploitation, and limited access to land and markets (Hentschel, Hruschka & Priester, 2003; Mining, Minerals and Sustainable Development, 2002). These characteristics illustrate the cycle of poverty that can exist in artisanal and small-scale mining communities, particularly where inefficient mining and processing techniques yield a small quantity of product and low profit (Barry, 1996). Further compounding this cycle are the health and environmental hazards associated with this type of work.

Artisanal and small-scale gold mining is carried out in over 70 countries by approximately 10-15 million miners including approximately 4-5 million women and children (United Nations Industrial Development Organization, 2006b; Telmer & Veiga, 2009). While ASGM activities occur all over the world, they are most prevalent in South America, Africa and Asia (Hinton, 2006; Böse-O'Reilly, World Health Organization, 2013a, 2014).

2.1 THE MINING PROCESS

ASGM, usually comprises the following steps:

a) **Extraction**: Miners exploit alluvial deposits (river sediments) or hard rock-deposits. Sediment or overburden is removed and the ore is mined by surface excavation, by tunnelling or by dredging (in the case of alluvial mining) (United Nations Environment Programme, 2015).

b) **Processing:** In this step, the gold is liberated from other minerals. The methods used for processing can vary depending upon the type of deposit. Gold particles in alluvial deposits are often already separated and require little mechanical treatment. While for hard rock deposits, crushing and milling are required. Primary crushing can be done manually, for example using hammers, or with machines. Mills are then used to grind the ore into smaller particles and, eventually, fine powder.

c) **Concentration:** In some cases, gold is further separated from other materials by concentration. Different methods and technologies (e.g. sluices, centrifuges, vibrating tables, etc.) may be used to concentrate the liberated gold. The density of gold compared with other minerals in the ore is often higher. Therefore many techniques utilize gravity for concentration (United Nations Environment Programme, 2012).

d) **Amalgamation:** Elemental mercury is used to obtain a mercury-gold alloy called an "amalgam" (roughly equal parts mercury and gold). There are two main methods used in ASGM for amalgamation: whole ore amalgamation and concentrate amalgamation. In whole ore amalgamation, elemental mercury is added with little prior comminution and concentration. Large quantities of mercury are often used (between 3-50 units per unit of gold recovered) and most is released as waste into the mine tailings because of the resulting inefficiency of this process (Sousa et al., 2010; United Nations Environment Programme, 2015). For these reasons, whole ore amalgamation is included in Annex C of the Minamata Convention on Mercury as an "action to eliminate" (United Nations Environment Programme, 2014). In concentrate amalgamation, the mercury is added only to the smaller quantity of material ("concentrate") that results from the concentration step. As a result considerably less mercury is generally used. Excess mercury can also be recovered. (United Nations Environment Programme, 2015).

e) **Burning:** The amalgam is heated to vaporize the mercury and separate the gold. In "open burning", all of the mercury vapour is emitted into the air. Open burning of amalgam or processed amalgam is, therefore, also considered an "action to eliminate" in Annex C of the Convention. The gold produced by amalgam burning is porous and referred to as "sponge gold" (United Nations Environment Programme, 2015).

f) **Refining:** Sponge gold is further heated to remove residual mercury and other impurities.

Throughout this work process miners as well as others living and working nearby to ASGM processing sites are exposed to a variety of environmental and occupational health hazards that will be discussed in later sections.

Methods and technologies used in the ASGM process can vary significantly from place to place. Environmental and occupational health hazards, and populations affected by those hazards, can also vary. Therefore, context specific responses are needed.

2.2 CHARACTERISTICS OF ARTISANAL AND SMALL-SCALE GOLD MINING COMMUNITIES

ASGM activities are quite diverse. Sometimes illegal or informal, often barely tolerated by authorities, ASGM activities can be either seasonal or year-round, long-term or following a boom-and-bust cycle (Buxton, 2013). ASGM demographics vary considerably, and all age groups can be represented. Communities may comprise local populations or may be generated through extensive in-migration. ASGM can be a family-based subsistence activity in which men, women and children participate throughout the mining work process. Some artisanal and small-scale gold miners are characterized as poor, migrant and seasonal workers who divide their time between mining and other economic endeavours (Phillips, Semboja & Shukla, 2001; World Health Organization, 2001).

While men work primarily in the mines, women and children can work both in and around the mines and at home, balancing mining and household responsibilities. This blend of mining and household work results in an array of health problems for miners, family members and surrounding communities: these are described in sections 3 and 4. Many of these health problems can be exacerbated by the absence of regulation in the ASGM sector; lack of miner education about health hazards; limited access to protective equipment and limited technical knowledge due to lack of access to technical training, low levels of education or low literacy rates (Wall, 2008). In cases where ASGM operates formally, health problems can be exacerbated by lack of miner access to technical and financial resources needed to adopt more sophisticated mining practices.

ASGM communities often have little or no access to safe drinking water, adequate sanitation or health care. The problem is compounded when mining occurs in remote locations or when massive in-migration increases patient flow and subsequent pressure on the local health-care system.

MALE MINERS

While gender roles may vary, in general, men have greater access to and control over land and resources (Eftimie et al., 2012). Men are typically more involved in decisions regarding mining exploration, prospecting and benefits distribution, while also being directly involved in the mining work process (Eftimie et al., 2012; Hinton, Veiga & Beinhoff, 2003a). A study of artisanal and small-scale gold miners in Mongolia found that male miners belonged to one of two groups, the first of which comprised men who had a long history in artisanal and small-scale mining and were more aware of the health risks associated with their work. The second group included younger men whose lack of experience resulted in more risk-taking behaviour, particularly in relation to the use of safety measures and personal protective equipment (Pfeiffer et al., 2013).

FEMALE MINERS

Female participation in artisanal and small-scale mining varies around the world: women make up 10% of the artisanal and small-scale mining population in Asia, 10-20% in Latin America and 40-50% in Africa (Hinton, Veiga & Beinhoff, 2003a). This variation is further reflected in their mining roles. While often excluded from underground extraction, women participate in a variety of tasks both inside and outside the mine (International Labour Organization, 2007). In the Philippines, for example, women are primarily involved in amalgamation and burning, while men are primarily involved in ore extraction and processing (Lu, 2012). In Bolivia, women mainly gather and process ore, often by hand, for example using sledge hammers (Bocangel, 2001). In Africa, female miners can take part in all aspects of mining - digging, crushing, transporting, sorting, processing and trading (Lu, 2012). Women are also often simultaneously responsible for all domestic tasks, such as preparing food, caring for children, cleaning, etc. (International Labour Organization, 2007). In some locations, women also supply food and drink, tools and equipment, and sexual services (Yakovleva, 2007).

CHILD MINERS

The ILO estimates that nearly one million children between 5 and 7 years of age are engaged in small-scale mining and quarrying activities worldwide (International Labour Organization, 2005). Children can be involved in virtually all stages of ASGM, ranging from ore extraction, to processing, and burning. Some children are also required to run errands, carry heavy equipment or materials, or deliver food and water to miners working deep within the mines (International Labour Organization, 2003). Tasks performed by young boys and girls also vary. For instance, girls involved in ASGM often participate in wet and dry panning, extraction, and amalgamation. Girls are also often involved in domestic activities in and around ASGM sites and processing areas. Boys on the other hand, are more typically involved in extraction and processing (International Labour Organization, 2005).

Almost all work performed by children in artisanal and small-scale mining is hazardous and has characteristics that fit the definition of a “worst form of child labour” under ILO Convention No. 182 (International Labour Organization, 2005). It is difficult, however, to eliminate or limit the participation of children in artisanal and small-scale mining, given its family orientation, transient and informal nature, and associated levels of poverty.

3 HEALTH HAZARDS

ASGM-related health hazards are categorized as chemical, biological, biomechanical, physical and psychosocial. The sections that follow summarize the most prevalent health hazards in each category, an overview of them being provided in Table 1. Hazards of particular relevance to vulnerable populations, such as children, women of child-bearing age, and pregnant women are also addressed.

3.1 CHEMICAL HAZARDS

Miners are susceptible to inhaling, absorbing and ingesting chemicals throughout the mining process. The most common chemical exposures in ASGM are to: mercury used to amalgamate the gold; cyanide used to extract gold, for example from tailings; and other chemicals contained in dust and gases.

MERCURY

People can be exposed to two forms of mercury in an ASGM context: elemental mercury and organic mercury.

Elemental mercury is used in the ASGM process to form gold amalgam. The most important direct route of exposure is by inhalation. Highest concentrations of elemental mercury vapours are released when the gold amalgam is heated, for example during the open burning step (as described in section 2.1). This heating process may occur onsite, or at gold shops, or at processing centres, many of which are located in populated areas. Individuals working in or living nearby these facilities and can thus be heavily exposed to elemental mercury vapour, often to degrees that exceed World Health Organization recommended limits (United Nations Environment Programme, 2012; Gibb & O'Leary, 2014).

Due to its high volatility, elemental mercury can transform from its liquid state into vapour at typical room temperatures (World Health Organization, 2003). Individuals can be exposed to elemental mercury vapour if liquid mercury is not properly stored or if surrounding surfaces have been contaminated. Mercury can also volatilize from contaminated waste materials at mining sites (e.g. tailings). Only small amounts of ingested elemental mercury, for example coming from contaminated hands, get absorbed in the gastrointestinal tract (World Health Organization, 2003).

Elemental mercury intoxication manifests in neurological, kidney and autoimmune impairment (World Health Organization, 2013a). Symptoms may intensify and/or become irreversible as exposure duration and concentration increase (World Health Organization, 2003). Acute inhalation can directly affect the lung, causing airway irritation, chemical pneumonitis, and pulmonary oedema, with consequent chest tightness and respiratory distress (Agency for Toxic Substances and Disease Registry, 2014). High inhalational exposures can also lead to respiratory failure and death (Landrigan & Etzel, 2013). Systemic absorption of elemental mercury via the lungs causes nausea, vomiting, headache, fever, chills, abdominal cramps, and diarrhea. When ingested, elemental mercury causes direct irritation of the gastrointestinal tract.

Chronic, lower level exposure to elemental mercury causes gingivostomatitis, photophobia, tremors and neuropsychiatric symptoms such as fatigue, insomnia, anorexia, shyness, withdrawal, depression, nervousness, irritability and memory problems (World Health Organization, 2003). It can also cause damage to the peripheral nerves and kidneys (Dart & Sullivan, 2004). Elemental and inorganic mercury toxicity in children can also manifest in oedematous, painful, red, desquamating fingers and toes (acrodynia), as well as hypertension (Böse-O'Reilly et al., 2010).

Under certain environmental conditions, mercury released into the environment can be transformed into an organic compound: methylmercury. Bioaccumulation occurs as large fish eat smaller, methylmercury-containing fish, increasing organic mercury concentrations as it moves up the food chain.

Due to its greater lipid solubility, methylmercury is more easily absorbed into the bloodstream via the gastrointestinal tract than elemental mercury. Absorption of methylmercury is usually in excess of 90% (World Health Organization, 1990). When circulated throughout the body, methylmercury crosses the blood-brain barrier and accumulates in the central nervous system. The peripheral nervous system and kidneys can also be affected. Symptoms of neurologic disease associated with methylmercury exposure include tingling in the extremities, headaches, ataxia, dysarthria, visual field constriction, blindness, hearing impairment, and psychiatric disturbance, muscle tremor, movement disorders, paralysis and death (Gibb & O'Leary, 2014).

Minamata Disease came to light in the 1950s as a result of methylmercury ingestion among fish-eating communities living near the Minamata Bay in Japan. Disturbances in motor and mental development ranged from very severe-newborns with a profound cerebral palsy-like presentation-to psychomotor impairment (e.g. abnormalities in chewing, swallowing, speech, gait, coordination, involuntary movement), personality impairment (e.g. extreme shyness, violent behaviour, restlessness, easy startling reflex, inattention or easy distractability), epileptic seizures, and neurological symptoms (e.g. numbness, tingling, abnormal sensory function) (Harada, 1995; Ekino et al., 2007). Studies of Minamata cases confirmed that methylmercury crosses the placenta with ease, and can result in cord blood concentrations that are higher than concentrations found in maternal blood (World Health Organization, 1990). Methylmercury is carried to the developing nervous system where it interferes with normal brain cell migration from the core to surface areas of the brain. In addition, methylmercury binds directly with neural chromosomes and halts cell division. This physiologic interference leads to changes that manifest in the typical neurologic abnormalities, described above. Health effects can vary depending on the dose (the frequency and concentration of exposure) and timing in the neurodevelopment of fetuses and children (World Health Organization, 1990).

Those groups at risk of methylmercury intoxication include individuals who consume large amounts of mercury-contaminated fish. ASGM populations who also are fish-eaters are at risk for mercury intoxication of both the elemental and the organic forms (Gibb & O'Leary, World Health Organization, 2013a, 2014) (see section 4 for more information on environmental pathways of mercury exposure).

Box 1: Prevention and reduction of exposure to mercury

Mercury substitution or reduction

The response to mercury exposure from ASGM focuses on elimination, substitution or reduction. Mercury exposure reduction methods include more effectively concentrating the gold (so as to reduce the quantity of mercury used in the amalgamation process), prohibiting the processing of mercury/gold amalgam in residential areas, using mercury capture devices such as retorts or fume hoods to capture mercury vapour emitted when the mercury/gold amalgam is burned, or use of mercury-free processes, such as gravity-only concentration methods. Applicability and feasibility under local conditions are major considerations in all of these techniques. If substitution and exposure reduction are not feasible, mine workers should be advised to work in well-ventilated areas situated downstream to any residences, to use respirators, gloves and tools and to keep contaminated clothes or materials at the worksite in order to minimize exposure (Böse-O'Reilly, 2014; United Nations Environment Programme, 2015).

Treatment of cases of mercury poisoning

Extensive information exists on the use of chelation therapy to treat acute mercury intoxication but information on treatment of chronic mercury toxicity among artisanal and small-scale gold miners is limited (Böse-O'Reilly, 2014). Moreover, there are no internationally-agreed protocols on the use of chelation therapy for the management of mercury intoxication in ASGM. Chelating agents such as dimercaptopropane sulfonate (DMPS) and succimer (DMSA) are used in the treatment of mercury poisoning, to increase urinary excretion of the metal. However, currently only one population-based study from the Philippines describes the use of DMPS as an antidote for mercury poisoning associated with ASGM (Böse-O'Reilly, 2003).

CYANIDE

Due to its high gold recovery rate and low cost, cyanide is increasingly used in ASGM, but often after mercury has already been used, for example on tailings (wastes). Mercury-cyanide compounds are easily dispersed in waters and, therefore, can enhance the mobility and/or bio-availability of mercury in the environment (United Nations Environment Programme, 2012). For this reason, the use of cyanide after the use of mercury is an "action to eliminate" in Annex C of the Minamata Convention on Mercury.

While cyanide does not persist in the environment, improper storage, handling and waste management can have severe human health and environmental effects (United Nations Environment Programme, 2012). Cyanide interferes with human respiration at the cellular level and can cause severe and acute effects including rapid breathing, tremors, asphyxiation and death (Lu, 2012). Chronic effects include neuropathological lesions, difficulty breathing, chest pain, nausea, headaches and enlarged thyroid gland (Hinton, Veiga & Beinhoff, 2003b; Agency for Toxic Substances and Disease Registry, 2011b).

CHEMICALS CONTAINED IN DUST

Silica is a mineral found in varying concentrations in ore of the type often mined in the ASGM process. Due to their small diameter and cystalline shape, silica dust particles generated during drilling, mineral extraction, ore crushing, and blasting, can be readily inhaled and deposited in the pulmonary tree (airways). Silica dust is toxic to lung tissue and to the immune system, causing progressive scarring (even after the exposure has stopped) and increased susceptibility to infectious agents in particular, tuberculosis (Rees & Murray, 2007; Gottesfeld, Andrew & Dalhoff, 2015). Silica is also classified as a lung carcinogen (Guha, Straif & Benbrahim-Talla, 2011).

The presence of other minerals associated with gold deposits, such as iron arsenic sulphide ($FeAsS$) or lead sulphide (PbS), can be hazardous, as well. Dust generation in the mining process may make these minerals bioavailable to miners and bystanders.

An incident of lead poisoning in Zamfara, Nigeria was a tragic reminder of the fact that in many instances artisanal and small-scale miners and their family members can be exposed simultaneously to multiple chemical hazards (see Box 2).

TOXIC GASES

Blasting generates a number of toxic gases such as sulfur dioxide, oxides of nitrogen and carbon monoxide. The use of petrol- or diesel-operated machinery, particularly in confined spaces where adequate ventilation is lacking, is also a major factor in exposure to carbon monoxide, which can cause lethal poisoning (Donoghue, 2004; Agency for Toxic Substances and Disease Registry, 2012). Furthermore, gases such as methane, oxides of nitrogen and others that occur naturally in underground mining may displace and reduce oxygen in confined spaces, causing asphyxiation.

Box 2: Lead poisoning among children of artisanal and small-scale gold miners in Zamfara, Nigeria

In March 2010, alarm was raised by a large number of unexplained deaths of young children in villages in Zamfara State, Nigeria (Médecins Sans Frontières, 2012). An investigation identified lead poisoning as the likely cause. The source of the lead exposure was found to be environmental contamination caused by the smashing and grinding of rocks containing not only gold ore but also high levels of lead (Dooyema et al., 2012). The processing of ore was carried out in the villages, often within family compounds. Environmental investigations found high levels of lead in these places as well as in community water sources (Dooyema et al., 2012; Lo et al., 2012). Children were intoxicated through inhalation and ingestion of lead particles in dust and soil, consumption of food already contaminated with soil and dust, and drinking from, contaminated water sources (Blacksmith Institute, 2011). It is estimated that over 400 children died from lead poisoning in Zamfara, and at least 3000 were poisoned (Médecins Sans Frontières, 2012). At the time, this was thought to be the largest outbreak of lead poisoning among children ever recorded (Burki 2012; Greig et al., 2014). More than 50 villages were involved in gold ore processing and at least half of them were shown to be highly contaminated with lead (Lo et al., 2012).

In order to address the environmental and health issues the Government of Nigeria, with the assistance of humanitarian agencies, provided medical care in the form of chelation therapy and health education, carried out environmental remediation, and advocated the use of safer mining practices (Médecins Sans Frontières, 2012). Local governments worked with several agencies to help move gold processing activities away from homes and village centres and to educate villagers about safe mining techniques (Plumlee et al., 2013). Between 2010 and 2011, the situation in seven villages was remediated by removing, replacing or covering contaminated soil, depending on its lead concentration levels (Blacksmith Institute, 2011). Children in these villages were, and some continue to be, treated with chelation therapy. Remediation and treatment for lead poisoning substantially decreased mortality rates in the affected villages (Médecins Sans Frontières, 2012; Thurtle et al., 2014). However, many children in unremediated villages continued to be poisoned by lead.

3.2 BIOLOGICAL HAZARDS

Although ASGM communities are susceptible to a variety of infections, very common biological hazards affecting them are waterborne and vector-borne diseases, sexually transmitted infections, HIV/AIDs, and tuberculosis.

Water and sanitation infrastructure is frequently lacking or inadequate in artisanal and small-scale mining camps because many sites are in remote locations that are hard to reach and the mining is often a transient activity. In some mining areas toilets are rare and pit latrines, if available, are usually shallow and can easily contaminate other water sources (Phillips, Semboja & Shukla, 2001) thus increasing the risk of waterborne diseases such as cholera. Stagnant water provides a favourable environment for reproduction of the mosquitoes that carry diseases such as malaria and dengue (Pommier de Santi et al., 2016). Water contamination associated with ASGM can occur in mines and households in the form of mine waste and chemical discharge (Hentschel, Hruschka & Priester, 2003).

The seasonal and migratory nature of ASGM can lead to high-risk behaviour that can facilitate the spread of sexually transmitted infections (STIs), HIV and AIDS (Centre for Development Studies: University of Wales, 2004). HIV infection coupled with occupational exposure to silica dust (see section 3.1) are important risk factors for tuberculosis, particularly among ASGM miners (Rees et al., 2010; Gottesfeld, Andre & Dalhoff, 2015).

3.3 BIOMECHANICAL AND PHYSICAL HAZARDS

Biomechanical hazards such as heavy workloads, repetitive tasks, long working hours and unsafe equipment can lead to the development of musculoskeletal disorders, the most common of which are shoulder disorders, fatigue and lower back pain (McPhee, 2004). Physical hazards form a broad category that includes vibration, loud noise, heat and humidity, and radiation, all of which are present in ASGM.

MUSCULOSKELETAL DISORDERS

Miners experience shoulder disorders as a result of heavy lifting such as overhead work while suspending pipes and cables (Donoghue, 2004). They also experience chronic injury and fatigue from carrying heavy materials over long distances, and bending over in awkward positions, for example during panning or while digging in cramped spaces (Hinton, Veiga & Beinhoff, 2003b).

OVEREXERTION

In artisanal and small-scale gold mining, overexertion results from uncomfortable postures and carrying out repetitive tasks using non-mechanized tools. Accidents caused by the repetitive use of sledgehammers, drills, pickaxes and rock crushers, while minor compared to those caused by power tools and electrical equipment, can result in serious injuries. Often, miners do not realize the extent of injuries resulting from overexertion and thus do not seek medical attention when needed (Hinton, 2006).

PHYSICAL TRAUMA

Trauma is a significant concern for miners (Navach et al., 2006). Traumatic injuries associated with ASGM include burns, eye injuries, fractures, impalement, and in some instances physical dismemberment (Calys-Tagoe et al., 2015; Long, Sun & Neitzel, 2015). These injuries are often caused by rock falls, explosions and the inappropriate and/or unsafe use of equipment. The latter can not only cause biomechanical injuries but also result in electrical shocks and thermal and electrical burns.

According to Hinton (2006), rock falls are a result of unstable pillars, substandard supports and waste rock being stored next to pits. Reportedly, many artisanal and small-scale miners die in tunnel accidents, under collapsed walls, or in open-pit mines (Hentschel & Hruschka, 2002). In Ghana, Kyeremateng-Amoah & Clarke (2015) found that injuries sustained by ASGM miners arise primarily because of unsafe working conditions and range from minor types such as contusions to severe types such as fractures and spinal cord injuries.

The use of explosives can result in exposure to dangerous levels of dust, noise and vibration and lead to asphyxiation and, in some cases, death due to acute traumatic injury (Harari & Harari Freire, 2013). Explosions can also occur when rudimentary tools are used to break up material containing unexploded or misfired explosives (Walle & Jennings, 2001).

NOISE

Many tasks carried out within the ASGM work process, for example extraction, crushing and milling, are associated with elevated occupational and community noise levels, often to levels that exceed WHO guideline limits for the prevention of hearing loss (Hinton, Veiga & Beinhoff, 2003; Eisler, 2003; Green et al., 2015).

Noise exposure is associated with the following health outcomes: hearing impairment, hypertension, ischemic heart disease, and stress (Basner et al., 2014; Green et al., 2015). Noise is also associated with sleep disturbance and cognitive impairment as well as social and behavioural effects including annoyance (World Health Organization, 2011).

HEAT AND HUMIDITY

The labour-intensive nature of ASGM can be compounded by extremely hot and humid working conditions. The health effects associated with heat stress are dizziness, faintness, shortness of breath or breathing difficulties, palpitations and excessive thirst (Walle & Jennings, 2001).

3.4 OTHER HAZARDS

Social, cultural and economic conditions can cause the emergence of psychosocial and physical hazards which manifest themselves in ways such as those listed below.

DRUG AND ALCOHOL ABUSE

Several studies have cited drug and alcohol abuse as a psychosocial hazard that affects both adult (mostly male) and child miners (Donoghue, 2004; International Labour Organization, 2006). The migratory nature of many people who engage in ASGM is believed to contribute to drug and alcohol abuse which are seen as a ways to cope with difficult circumstances (Hinton, Veiga & Beinhoff, 2003b; Thorsen, 2012).

VIOLENCE

Alcohol and drug abuse can lead to violence against partners, co-workers and community members. This has been well described in analogous scenarios, where subsistence work in settings far from home is associated with drug and alcohol abuse and consequent violence (Hinton, 2006). Prostitution is also a factor in some places. However, in many cases violence is not alcohol-related and can be associated with stressful working conditions, forced child labour and criminal activities such as extortion, theft, sexual violence or intimidation. Where ASGM operations are viewed as illegal, conflicts can lead to an escalation of violence between miners, authorities and local land users.

NUTRITIONAL DEFICITS

Food security is an important motivator of ASGM operations which are frequently poverty-driven. Many miners already find it difficult to secure adequate food for their families. Nutritional deficits can be exacerbated in ASGM camps where foodstuffs may be hard to access, for example because of rising costs of local goods and/or deterioration in quality of agricultural lands (Hinton, 2006; Buxton 2013). Changes in availability of disposable income among ASGM communities may also have an impact on quality of diets and therefore on nutritional status. For example, Long, Renne and Basu (2015a) found that residents of ASGM communities in Ghana reported lower fruit and vegetable consumption and higher sugar and fat consumption than residents of surrounding areas. The latter were reportedly more reliant upon locally grown food items, while the former were thought to consume more packaged foods and foods prepared by local vendors (Long, Renne & Basu, 2015a).

Table 1. Summary of health hazards related to ASGM

Hazard category	Hazard type	Sources of exposure	Health outcome	Sources of evidence[a]
Chemical	Mercury (elemental)	• Mercury release during gold amalgamation and mercury removal (“burning off”) processes	• Erethism (excitability) • Irritability • Excessive shyness • Insomnia • Severe salivation • Gingivitis • Tremors • Kidney disease • Acute gastrointestinal effects • From direct inhalational exposure: chemical pneumonitis, pulmonary oedema	Dart & Sullivan, 2004; Landrigan & Etzel , 2013; World Health Organization, 2010b; World Health Organization, 2013a; Kristensen, Thomsen & Mikkelsen, 2013; Agency for Toxic Substances and Disease Registry, 2014; Gibb & O'Leary, 2014; Basu et al., 2015; Rajaee et al., 2015a; Rajaee et al., 2015b
	Mercury (methyl-)	• Mercury bioaccumulated in the environment and food chain • Consumption of mercury contaminated fish and shellfish	• Visual disturbance - e.g. scotomata, visual field constriction • Ataxia • Paresthesias (early signs) • Hearing loss • Dysarthria • Mental deterioration • Muscle tremor • Movement disorders • Paralysis and death (with severe exposure) • Prenatal exposure: fetal toxicity, cognitive and motor delays and impairment	Dart & Sullivan, 2004; Landrigan & Etzel, 2013; World Health Organization, 2010b; World Health Organization, 2013a; Agency for Toxic Substances and Disease Registry, 2014; Gibb & O'Leary, 2014; Basu et al., 2015; Rajaee et al., 2015a; Rajaee et al., 2015b
	Silica	• Prolonged dust inhalation during drilling, mineral extraction, ore crushing and blasting	• Silicosis • Chronic obstructive pulmonary disease • Tuberculosis • Lung cancer	International Agency for Research on Cancer, 1997; Walle & Jennings, 2001; Donoghue, 2004; Hinton, 2006; Rees & Murray, 2007; Gottsfeld et al., 2015
	Arsenic*	• Arsenic inhalation and ingestion during copper, gold and metal mining activities	• Hyperpigmentation • Depigmentation • Bladder cancer • Skin cancers • Peripheral neuropathy • Lung cancer	Paul, 1993; International Agency for Research on Cancer, World Health Organization, 1997; Donoghue, 2004; Milton et al., 2005; von Ehrenstein et al., 2006; Hinton, 2006; Agency for Toxic Substances and Disease Registry, 2010; Ono et al., 2012; Ono et al., 2015
	Lead*	• Inhalation and ingestion of lead contaminated dust released by grinding ore to extract gold	• Death • Lead encephalopathy • Impaired neurocognitive development • Abdominal colic • Anorexia • Premature birth	World Health Organization, 2010a; Médecins Sans Frontières 2012; Thurtle et al., 2014

Hazard category	Hazard type	Sources of exposure	Health outcome	Sources of evidence[a]
	Methane, sulfur dioxide, nitrous oxide	• Methane gas released in underground coal mines • Sulphur dioxide and nitrous oxide released during the blasting phase and tailings collection	• Respiratory tract irritation • Asphyxiation from lowered oxygen levels due to displacement by gases	Hinton, 2006; Landrigan & Etzel, 2013
	Carbon monoxide	• Produced when petrol/diesel-fuelled equipment is used in a poorly ventilated space	• Headache • Nausea, vomiting • Confusion • Drowsiness • Coma • Death	Agency for Toxic Substances and Disease Registry, 2012
	Cyanide	• Gold extraction/leaching for example from tailings	• Neuropathological lesions • Visual impairment • Chemical asphyxiation/death	Hinton, Veiga & Beinhoff, 2003a; Hinton, Veiga & Beinhoff, 2003b; Agency for Toxic Substances and Disease Registry, 2011b Lu, 2012; Eftimie et al., 2012
Biological	Pathogenic microorganisms such as those causing cholera, malaria, dengue fever	• Contaminated and stagnant water in mines and homes	• Cholera • Malaria • Dengue transmission • Other vector-borne diseases	Phillips, Semboja & Shukla, 2001; Hentschel, Hruschka & Priester, 2003; Pommier de Santi et al., 2015
	Sexually transmitted infections, HIV	• High risk sexual activity • Unsafe health behaviours	• STIs • HIV • AIDS	Campbell, 1997; Centre for Development Studies: University of Wales, 2004; Hinton, 2006
Biomechanical	Musculoskeletal disorders	• Heavy lifting • Awkward working positions	• Shoulder disorders • Lower back pain • Chronic injuries • Fatigue	Hinton, Veiga & Beinhoff, 2003b; Donoghue, 2004
	Overexertion	• Uncomfortable postures • Repetitive tasks using non-mechanized tools	• Muscle strain • Tendinitis • Nerve impingement (e.g. carpal tunnel syndrome)	Hinton, 2006
	Trauma	• Use of inappropriate equipment • Rock falls • Explosions	• Contusion • Fractures • Spinal cord injuries • Electrical shocks • Electrical burns • Thermal burns • Chemical burns • Eye injuries	Hentschel, Hruschka & Priester, 2003; Hinton, 2006; Scott et al., 2009; Kyeremateng-Amoah & Clarke, 2015

Hazard category	Hazard type	Sources of exposure	Health outcome	Sources of evidence[a]
Physical	Loud noise and vibration	• Noisy tools • Blasting • Drilling • Crushing • Ore processing	• Hearing impairment or loss • Numbness in hands and arms • Gangrene (extreme cases)	Amedofu, 2002; Eisler, 2003; Hinton, 2006; Brits, 2012; Saunders et al., 2013
	Heat and humidity	• Underground mines	• Dizziness • Faintness • Shortness of breath or breathing difficulties • Palpitations • Excessive thirst	Walle & Jennings, 2001; Donoghue, 2004
	Radiation*	• Radon (naturally occurring in some places including in soil)	• Lung cancer	International Atomic Energy Agency, 2002; International Atomic Energy Agency, 2011; International Atomic Energy Agency, 2013
	Low oxygen levels	• Displacement of oxygen by other gases	• Increased breathing rate • Dizziness • Nausea • Headache • Coma • Asphyxiation • Death (extreme cases)	Walle, 2007
	Electricity	• Direct or indirect contact with live wires or faulty electrical equipment	• Burns • Electrocution	Donoghue, 2004; Long et al., 2015a
	Explosives	• Black powder • Nitroglycerine • Dynamite • Dust • Noise • Vibration	• Heart attack • Hearing loss • Vibration-related injuries	Harari & Harari Freire, 2013
Psychosocial	Drug and alcohol abuse	• Transient lifestyle	• Liver inflammation • Neurological diseases • In extreme cases, violence against partners, co-workers and community members	Hinton, Veiga & Beinhoff, 2003b; Donoghue, 2004; International Labour Organization, 2006; Hinton, 2006; Thorsen, 2012
	Stress	• Lifestyle factors (poverty, separation from family, long working hours, social isolation, cramped living conditions, loss of work due to injury, fear of authorities, fear of injury or death)	• Stress reaction (e.g. anxiety, depression, insomnia, somnolence, changes in appetite)	Hinton, 2006
	Fatigue	• Artisanal and small-scale mining work characteristics (long work shifts, heavy workloads, repetitive actions)	• Fatigue • Pre-disposition to injury	New South Wales Mine Safety Advisory Council, 2009

*These hazards are location specific and are not necessarily present in all ASGM contexts.

[a] Sources of evidence include toxicology references and epidemiological studies that show an association between health hazards and health outcomes. Where available, references in an ASGM context are provided. In places where there is limited epidemiological evidence specific to ASGM, more general references are given.

3.5 SPECIAL CONSIDERATIONS FOR WOMEN AND CHILDREN

Women perform many tasks in and around the ASGM process and are subsequently exposed to many of the environmental and occupational health hazards described previously in this section as well as in Table 1.

Reproductive age women transfer risk to their developing fetuses if exposed during pregnancy or from toxins that accumulate in their bodies prior to pregnancy. The reproductive health hazards associated with ASGM include mercury, arsenic, lead, sulfur, nitrogen oxides and cyanides and heat (Jensen, Bonde & Joff, 2006; Böse-O'Reilly et al., 2008a; Ziskin & Morrissey, 2011; Charles et al., 2013; Landrigan & Etzel, 2014).

Adverse social behaviours associated with ASGM, such as drug and alcohol abuse as well as stress, constitute further hazards to reproductive health. Irrespective of the context, exposure to these hazards and behaviours may result in reduced fertility or cause infertility, menstrual disorders, early menopause, diminished libido, and early onset of puberty. For pregnant women, exposure to these hazards can lead to spontaneous abortions, while their offspring may have birth defects, development disorders, impaired cognition and low birth weight (Paul, 1993; Milton et al., 2005; von Ehrenstein et al., 2006).

In contexts where artisanal mining occurs outside of formal governmental regulation, especially when carried out in remote locations, woman can face additional risks due to their social isolation and vulnerability to physical and sexual abuse (Kelly, King-Close & Perks, 2014). Lack of access to safe and equitable employment opportunities in the ASGM sector can further enhance these vulnerabilities (Kelly, King-Close & Perks, 2014)

Like women, children involved in ASGM face a myriad of health risks, many of which are exacerbated by their ongoing physical, intellectual and emotional development. The health hazards associated with child labour in artisanal and small-scale mining are many, the most prevalent being malnutrition, thermal injuries and skeletal damage (Wasserman 1999; Hinton et al., 2003a). Young boys are often exposed to the ergonomic and biomechanical hazards associated with digging, grinding, crushing and moving materials, while young girls are additionally vulnerable to sexual exploitation and prostitution (Hinton, Veiga & Beinhoff, 2003a).

If mercury exposed children have escaped neurodevelopmental damage and other adverse health effects in utero, due to their ongoing physiological development and growth processes, mercury exposure during early childhood may also lead to profound neurologic and systemic damage (Böse-O'Reilly et al., 2010).

Böse-O'Reilly et al. (2008) have documented evidence of elevated blood mercury levels as well as typical signs of mercury intoxication, for example ataxia, among children who work in or live near ASGM communities. Children in ASGM communities have also been found to have urinary mercury concentrations - a measure of exposure to elemental mercury - at, and in excess of, levels associated with neurologic and kidney damage (World Health Organization, 2013a; Gibb & O'Leary, 2014).

Due to the particular vulnerability of children, women of child-bearing age, and pregnant women, strategies to prevent exposure of these population groups to mercury used in ASGM must be included in national action plans developed to support the implementation of Article 7 of the Minamata Convention on Mercury (United Nations Environment Programme, 2014).

4 ENVIRONMENTAL HAZARDS THAT HAVE IMPLICATIONS FOR HEALTH

The ASGM process frequently leads to degradation and contamination of the general environment. These environmental hazards have implications for the health and well-being of miners, surrounding communities as well as for the global environment. The most commonly cited ASGM-associated environmental hazards include land degradation, mercury emissions/pollution, siltation, erosion and water contamination.

Land degradation, in the form of clearing of large areas of forest and vegetation in order to mine ore, results in short- and long-term environmental and health effects. The creation and subsequent abandonment of pits and trenches leave surrounding communities susceptible to loss of arable land, loss of livestock, lack of clean water, stagnant water and malaria-carrying mosquitos (Hilson, 2001). Environmental degradation can also have a major impact on availability of food particularly where it affects agriculture, fishing, hunting and gathering, or other subsistence activities carried out to produce or procure food.

The contamination of Minamata Bay in Japan in the 1950s engendered an understanding of how elemental mercury is transformed in the environment and the consequent health effects. ASGM activities result in 727 tonnes of mercury being emitted into the air each year (United Nations Environment Programme & Arctic Monitoring and Assessment Programme, 2013), making ASGM the single largest anthropogenic source of mercury emissions to the environment. In recognition of the significance of this pollution source, the Minamata Convention on Mercury includes a specific Article addressing this practice (see section 1.2).

As described in section 3.1, vaporized (elemental) mercury is released during the burning process, emitted into the atmosphere, and later, once oxidized, deposited into soil, lakes, rivers and oceans (United Nations Environment Programme & Arctic Monitoring and Assessment Programme, 2013). Bacteria can transform mercury released into the environment into methylmercury which accumulates in the food chain, affecting fish and shellfish. People whose diet depends heavily on such food are thus exposed to mercury and can have severe adverse health effects (as described in section 3.1).

5 TRAINING MATERIALS TO ADDRESS HEALTH ISSUES ASSOCIATED WITH ARTISANAL AND SMALL-SCALE GOLD MINING

Health-care providers can play an important role in identifying, preventing and treating adverse health effects among ASGM workers and communities. They also can play a key role in raising awareness among these populations about opportunities to prevent such health effects.

5.1 RATIONALE FOR TRAINING FOR PRIMARY HEALTH-CARE PROVIDERS

In 2007, the 60th World Health Assembly (WHA) endorsed the "Workers' Health: Global Plan of Action" (WHA 60.26) which encourages countries "to develop and make available specific guidelines for the establishment of appropriate health services and surveillance mechanisms for human and environmental hazards and diseases introduced into local communities where mining, other industrial and agricultural activities have been set up to meet the associated needs of those communities;...". Primary care providers such as nurses, community health workers and general family physicians may be the first point of contact for workers exposed to health hazards associated with artisanal and small-scale mining. Therefore, it is crucial to enhance their knowledge of occupational and environmental health, as well as their sensitivity to this special workforce, which in some instances may include children. This will enable primary care providers to make the appropriate diagnosis and to treat acute illnesses and injuries among artisanal miners. Moreover, such enhanced knowledge is critical for the conceptualization and application of more holistic interventions and for seeing specific illnesses and injuries as markers of risk for the worker/patient, the family and the surrounding community.

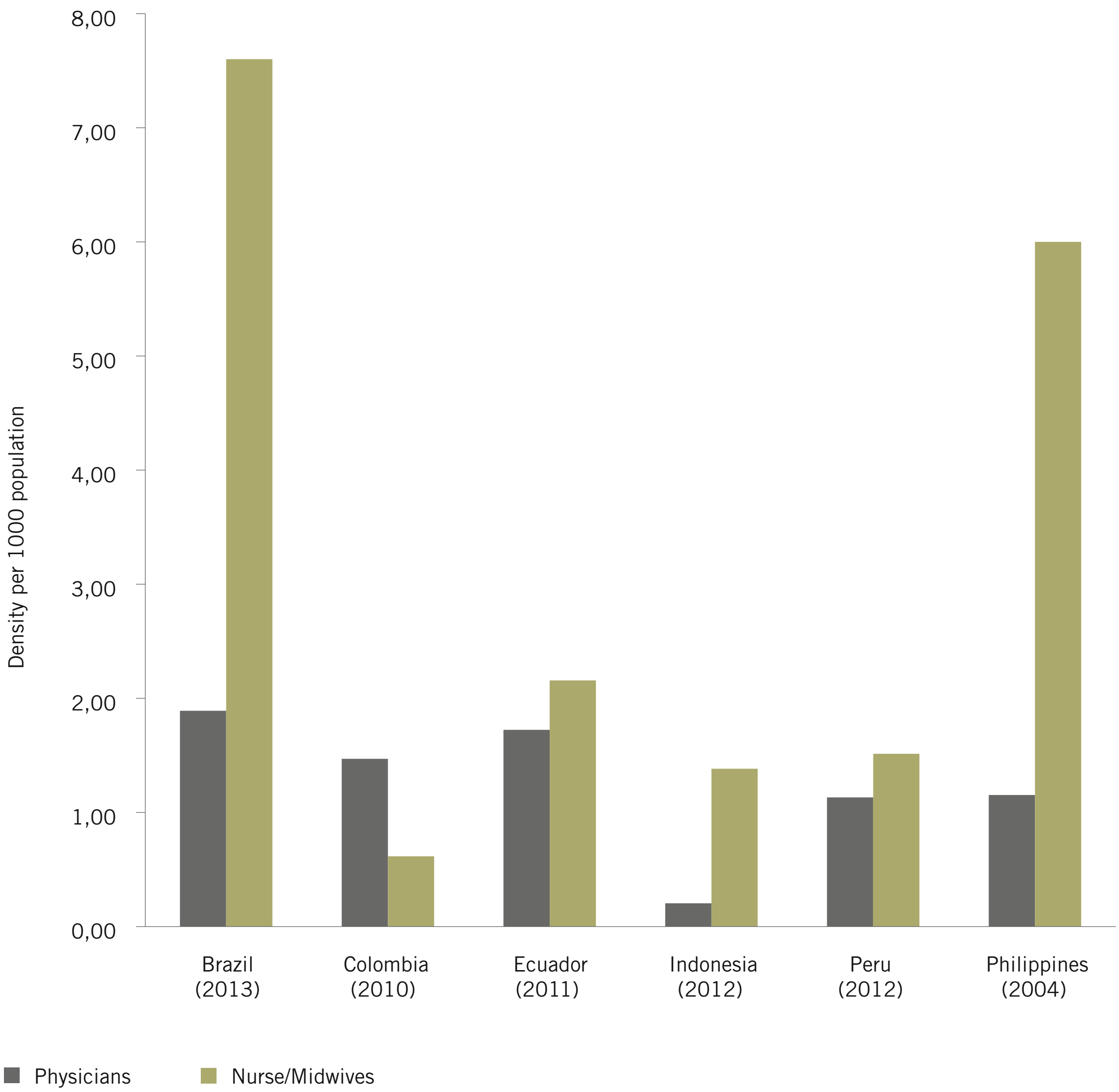
WHO collects data and maintains a database on human resources in primary health care in order to inform policy and resource allocation decisions at national and international levels (World Health Organization, 2013b). The distribution of different elements of the health-care workforce in selected countries where ASGM occurs is shown in Fig. 1. In nearly all countries shown, nurses and midwives form the largest part of the health-care workforce. Physicians, and environmental and occupational health specialists in particular, form a very small proportion of the health-care workforce. Curriculum content and pedagogic techniques used to train health providers on ASGM-related issues thus need to be adapted appropriately. For example, physicians are most familiar with lectures and slideshows as educational tools and already have considerable training in physical diagnosis and all organ systems. Nurses, nurse midwives, community health workers and pharmacists may have varied levels of training and experience in clinical diagnosis and may derive more learning from active educational techniques.

5.2 TRAINING FOR PRIMARY HEALTH-CARE PROVIDERS

Training resources for health-care providers that directly address ASGM-related health issues are scarce. However, case studies, toxicology and occupational health literature and publications from governmental and nongovernmental organizations do contain or suggest health components that could be developed further for use in this context.

Training sessions specifically for health-care providers were held in two ASGM countries (Indonesia and the United Republic of Tanzania) under the Global Mercury Project (Böse-O'Reilly et al., 2008b) and, in collaboration with WHO, in Mongolia in 2013. The non-governmental organization Artisanal Gold Council has also conducted training of health workers in 2012 and 2015 in Burkina Faso and Senegal and has developed information materials on ASGM for health professionals (Richard, Moher & Telmer, 2015).

Fig. 1. Health workforce in selected countries with ASGM in their territories[a]



Source: WHO Global Health Workforce Statistics (http://www.who.int/hrh/statistics/hwfstats/en/, accessed 14 September 2014).

[a] Countries shown have either already drafted national action plans on ASGM (Indonesia and the Philippines), formally notified the Minamata Convention Secretariat that they have more than insignificant ASGM in their territories (Columbia, Ecuador, and Peru) or have requested technical support from the United Nations Environment Programme (Brazil) to initiate the development of national action plans (Kenneth Davis, United Nations Environment Programme, personal communication, 16 February 2016). Countries shown also have mean annual ASGM mercury emissions of 45 tonnes/a or higher (United Nations Environment Programme & Arctic Monitoring and Assessment Programme, 2013).

WHO has developed a series of training modules to address a range of the environmental and health issues that have an impact on children. Health hazards addressed include mercury, lead, arsenic, radiation and noise (World Health Organization, 2008).

Other training materials are also available that can be adapted by inserting artisanal and small-scale mining content into already evaluated lectures, exercises and activities in the realm of occupational health and safety (Great Lakes Center for Occupational and Environmental Safety and Health, 2005; Workers' Health Education, 2011, World Health Organization, 2001).

5.3 TRAINING FOR MINERS

Until recently, published resources on worker training specifically related to ASGM were limited (United National Industrial Development Organization, 2006), although extensive literature exists on general worker training, including training methodology and occupational safety and health content targeted to immigrant workers and those with low literacy levels. Improved awareness of the health hazards faced by miners is needed in order to introduce better, healthier and more environment-friendly mining technologies (Hilson et al., 2007; Peplow & Augustine, 2007).

6 CONCLUSION

Globally, ASGM is a major contributor to the formal and informal economic sectors. The continued growth of ASGM means that its associated environmental hazards and adverse health impacts will continue to be important problems. This is a complex issue and it is evident that health-care providers need further education and training on screening and surveillance of artisanal and small-scale gold miners and on how to develop a dialogue with miners in order to understand their conditions better and to treat them effectively. Similarly it is critical to educate miners, their family members and communities about ASGM hazards to human health and the environment.

As long as mercury is used in abundance in ASGM, there is a serious threat to the health of miners, the surrounding communities and, in particular, children and pregnant women. There is sound evidence that mercury - in both its elemental and organic forms - has adverse neurological effects and is particularly toxic during fetal development and childhood.

Primary health-care providers generally lack knowledge about, and sensitivity to, environmental and occupational illnesses and the adverse health effects of elemental mercury used in ASGM in particular. Knowledge is also lacking about how to advise patients on preventive practices, when to intervene, when to treat and when to refer cases of concern.

The promulgation of and global support for the Minamata Convention on Mercury provide an opportunity to enhance awareness and promote the provision of advice and interventions by primary health-care providers in ASGM communities. The health sector has clearly recognized its role in supporting the implementation of the Minamata Convention, as evidenced and outlined in resolution WHA67.11 adopted by the Sixty-seventh World Health Assembly in May 2014.

If appropriately trained, health-care providers, and nurses and community health workers in particular - given their numbers and proximity to ASGM communities - can play a key role in efforts to raise awareness and address health problems associated with ASGM. They can also be mobilized to help raise awareness about the need to adopt safer and more environmentally friendly ASGM work processes, including as part of efforts to reduce and eliminate the use of mercury in ASGM. Although training materials for primary health workers are available, few address ASGM-related issues or are suitable for use in training different types of health-care providers. This points to an urgent need for further work in this area.

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Department of Public Health, Environmental and Social Determinants of Health (PHE)
World Health Organization (WHO)
Avenue Appia 20, CH-1211 Geneva 27, Switzerland
www.who.int/phe/en/