**Initiatives to combat mercury use in Artisanal Small Scale
Gold mining: A review on issues and challenges**

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Complete List of Authors:	Malehase, Tshia; Tshwane University of Technology, Department of Environment, Water and Earth Sciences Okonkwo, Jonathan; Tshwane University of Technology, Daso, Adegbenro; Tshwane University of Technology, , Department of Environmental, Water and Earth Sciences, Faculty of Science
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Initiatives to combat mercury use in Artisanal Small Scale Gold Mining: A review on issues and challenges

Tshia Malehase, Adegbenro P. Daso, Jonathan. O. Okonkwo

Department of Environmental, Water and Earth Sciences, Tshwane University of Technology, Private Bag X680, 175, Nelson Mandela Drive, Arcadia, Pretoria, 0001, South Africa.

Email: OkonkwoOJ@tut.ac.za, Tel: +27 12 382 6245

Abstract

The Minamata Convention on mercury has received a number of criticisms and challenges that potentially hinder its progress on reducing and controlling mercury use and release by Artisanal Small Scale Gold Mining (ASSGM). The resulting weak environmental control has repercussions for the social and environmental wellbeing of countries that subsist on ASSGM in their territory. Lack of distinguishing and categorizing ASSGM, the absence of a contextual implementation plan, and no defined means of communication are some of the aspects that lead to unsuccessful initiatives, particularly on effectively introducing mercury-free technologies. Moreover, an underestimation of the active mining population implies that the problem is greater than what is perceived. ASSGM is a viable source of poverty alleviation which cannot be ignored and therefore the resulting socio-economic and environmental challenges need to be addressed while optimizing economic benefits. In this paper a compendium of issues and challenges that need to be addressed to reduce and control mercury use and release by ASSGM are discussed. By reviewing the challenges of successful case studies, a comprehensive approach is proposed to enhance the implementation of the Minamata Convention on mercury.

Keywords: Minamata Convention, artisanal and small scale gold mining, top down-bottom up approach, amalgam, mercury

1. Introduction

Artisanal and small scale gold mining (ASSGM) is one of the major sources of global mercury pollution and the sector is currently receiving the highest international attention due to the resulting socio-economic and environmental effects caused by this activity. In 2013, it was estimated that approximately 727 t (metric tonnes) of mercury has been released into the atmosphere, which account for approximately 37% (1960 t) of anthropogenic global mercury emissions (UNEP 2013). Approximately 800 t of mercury is released into the environment annually by ASSGM (Basu et al. 2015). ASSGM contributes significantly to the total global gold production, producing between 380-450 t of gold per year (Seccatore et al. 2014). Developing countries account for the highest number of ASSGM operations using the lowest available technology. The quality and environmentally friendly nature of ASSGM technology differs from one region to another. For example, in South America, one of the most environmentally friendly techniques is employed (Seccatore et al. 2014). Other strong examples of environmentally friendly ASSGM practices can be found in Central Asia and Central America. In contrast, environmentally unfriendly techniques appear to be most common in Africa (Seccatore et al. 2014). Consequently, sub-Saharan African countries are one of the leading mercury emitting regions in the continent. East Asia appears to be in the same category with the sub-Sahara African Countries (Basu et al. 2015).

ASSGM description has been generalized over numerous artisanal and small scale mining (ASSM) activities even though different minerals and methods are employed, formal or informal, and poses different degrees of social and environmental impacts. A more definite description is needed when dealing with the technical aspects of ASSGM (Seccatore et al. 2014). Recently, Saccatore et al. (2014) estimated that the number of ASSGM to be over 16 million miners who may be directly involved in the mining operations. The estimations on the number of ASSGM population in the literature lack consistency and it is largely underestimated when considering an increasing population and unemployment rates in most developing countries. One of the most basic steps that need to be addressed is an accurate estimate of the global ASSGM population. A number of initiatives to introduce new and improved technology have been undertaken with limited success due to a variety of reasons which mainly includes complex technology and methods, less profit returns, and a lack of training and education. This review argues that it is important to understand area-specific socio-economic and environmental conditions that affect the needs of miners, the importance of training and education, and the necessity to provide financial support in order to effectively introduce a sustainable technology. Because there is growing evidence of socio-economic, environmental and policy challenges that hinder achieving the objectives of reducing, controlling, monitoring, eliminating mercury releases, and emissions by ASSGM, implementing sustainable technology becomes extremely complex (Hilson and McQuilken 2014). Furthermore, suggestions on how countries can prepare and implement the treaty requirements given the region-specific identified challenges, are not clear. Recent studies (Davis 2014; Sippl 2015; Langston et al. 2015) have inadequately pinpointed strategies that can assist governments on formalizing

ASSGM, as it is one of the requirements of the Minamata Convention on mercury, whereas the majority of studies have failed to recognize the convention and therefore they do not provide suggestions for cost-effective strategies that would implement the objectives of the convention (Bakia 2014; Hilson and McQuilken 2014; Hilson and Gatsinzi 2014; Veiga et al. 2014; Dondeyne and Ndunguru 2014; Ncube-Phiri et al. 2015; Oramah et al. 2015; Weng et al. 2015). In this review, a collective summary of the aforementioned issues and challenges are presented. Thereafter, a suggestion of communication structure is proposed for countries to be able to successfully formalize and combat mercury use in the ASSGM.

2. The initiative to combat mercury use in ASSGM

In view of the mercury poisoning incidences reported throughout the world, the United Nations Environmental Programme (UNEP)'s and Governing Council (GC) initiated global assessment of mercury in 2001 and this has precipitated the Minamata Convention on mercury. The Minamata Convention on mercury has been established as an initiative to reduce global mercury pollution. The treaty has mandated countries "signatories" having ASSGM operations within their territory to take steps to reduce, control, monitor and where feasible, eliminate the use of mercury and mercury compounds, and the emission and release of mercury into the environment. However, the convention has received a lot of criticism pointing at unclear implementation plans, lack of resources in developing countries and the diversity of the factors that exacerbate the ASSGM operation such as poverty, lack of economic alternatives and poor governance. Sippl (2015) has outlined major problems that often lead to the ineffectiveness of

international policies such as the Minamata Convention on mercury which include lack of resources, poor regulations and implementation plans.

Since then, UNEP has undertaken to increase the understanding of mercury releasing sources to the environment as it is critical for the development of relevant and cost-effective strategies towards the reduction of this global pollutant. Amongst other requirements, the treaty requires signatories that have ASSGM within their territory to take steps to; develop, submit and implement a national action plan, strategies to prevent mercury pollution, education, research, dissemination of information, and provision of technical and financial support as means of remediating mercury pollution (USEPA 2014). The Minamata Convention on mercury made a bold step to abolish primary mercury mining, with an exception that those mines already operating, may continue for 15 years after the treaty has come into effect. More importantly, mercury mined during the provided period will only be used in the manufacturing of mercury added products. Hence, the direct use of mercury such as in ASSGM should be abolished. It is anticipated that the availability of mercury will decline as a result of enforcement of international policies that phase out mercury use and supply. However, the use of mercury has been regulated over the past decade in some countries such as China, Ghana and Tanzania, with little effect on mercury availability and use (Styles et al. 2010; Viegas et al. 2014). The suppliers of “black market” mercury are one of the aspects that have not been entirely researched. This will undoubtedly be a future problem enhancing mercury use in the sector.

3. The paradox on ASSGM description

107 The Minamata Convention on mercury defines ASSGM as “gold mining conducted by individual
108 miner or small enterprise with limited capital investment and production”. There are different
109 descriptions set by different organizations and commentators, a number of them are outlined
110 by Hilson and McQuilken (2014), and they vary from country to country (Weng et al. 2015).
111 Saccatore et al. (2014) have raised the issue of inconsistency in the description and they
112 proposed a more general definition. ASSGM definition is generalized over a wide range and
113 diversity of artisanal and small scale mining (ASSM) activities. This creates the perception that
114 all ASSM activities employ mercury. For example, in South Africa, there are formalized ASSM
115 using rudimentary techniques that do not involve the use of mercury in gold mining. Moreover,
116 there are mercury-free techniques such as igoli which is widely used in South Africa and in
117 some countries in Africa. This method only involves leaching the gold concentrates with
118 hydrochloric acid and bleach, filter and precipitate gold with sodium metabisulphate (Mintek
119 2011). There are a handful of descriptions of ASSGM, which are defined differently in different
120 countries taking into account the volume of production and output, the amount of capital
121 invested, the size of working force, the size of a claim, the depth of the mine and the level of
122 technology being used (Collins and Lawson 2014). The majority of the descriptions describe
123 ASSGM as mining activity that is characterized by the use of rudimentary processes and
124 technology to extract valuable minerals from primary and secondary ore bodies, lack of long-
125 term mine planning, rehabilitation measures and monitoring. The description can refer to illegal
126 or legal, formal or informal and it encompasses every activity from individual micro gold miner
127 to medium-scale operations employing thousands of people (Weng et al. 2015). Saldarriaga-
128 Isaza et al. (2013) found commonalities on the description of ASSGM in different countries

which include low levels of mechanical technology use, labour intensiveness, low environmental awareness, poor education and training, high transience among some miners and lack of financial savings. These definitions are not clear on whether they refer to formalized, illegal or mercury employing miners. For clarity, a fundamental initiative that describes the term is to shift from using such a general term. Rather, ASSM description must enable one to distinguish the difference from Illegal Artisanal Small Scale Mining (IASSM), Illegal Artisanal and Small Scale Gold Mining (IASSGM), Legal Artisanal and Small Scale Gold Mining (LASSGM), Mercury Employing Artisanal and Small Scale Gold Mining (MEASSGM) and Non-Mercury Employing Artisanal and Small Scale Gold Mining (NMEASSGM). This will provide a more definite description that is needed to clarify the type of ASSM practices on a global perspective especially when dealing with technical matters. For example, ASSM might also refer to the rudimentary extraction of a wide range of ferrous and non-ferrous metals, stones and sand, employing a variety of mining methods and where different numbers of miners are involved.

4. Different methods of gold extractions used by ASSGM

The operational and processing methods used by ASSGM are well reported, as well as alternative methods to reduce and combat mercury use in the sector (Styles et al. 2010; Davis 2014). These methods include milling, disc mills, sluice box, coal-oil agglomeration, centrifuges, magnets, Gemini tables, cyanadation, barox and amalgamation to mention but a few. The majority of these methods are inappropriate, expensive and some take longer to obtain the final product. For example, the sluice box and retorts are inappropriate to be carried out by

miners and it is time consuming, although they are cheaper and environmentally sound when compared to amalgamation.

The most popular method used by miners is amalgamation of gold ores or gold concentrates to extract valuable gold from its ores because it is easy to use and miners believe it to be less expensive than other methods (Jönsson et al. 2013; Saldarriaga-Isaza et al. 2013; Davis 2014). During the mining process, mercury can be used at different stages of gold extraction. This includes miners injecting mercury into the pit to collect fine gold; milling, where mercury is placed in the ball mills; and sluicing, where mercury is placed in a sluice box for agglomeration of small particles for easier capturing; panning, where mercury is added to the black sand in a pan, rolled and rubbed through the sand for optimum contact with gold grains to eventually form a gold-mercury amalgam paste. The sand is gradually washed away during the panning process, leaving only the amalgam paste behind. Thereafter, the amalgam paste is heated over a fire or with a blowtorch to drive off mercury as a vapour, leaving behind a yellowish-brown sponge gold. In many cases, the amalgam paste is firstly squeezed (e.g. in a cloth) to eliminate excess liquid mercury that will later be reused (Viega et al. 2014).

Styles et al. (2010) have demonstrated that, despite the simplicity, easy access and favourable use of mercury, the method is inefficient and presents deleterious effects on human health and the environment. Several projects have been initiated to introduce sound technology within the sector, amongst others, the UNIDO Mercury Project have campaigned for the use of safer methods such as retorts in Ghana and Tanzania (Styles et al. 2010; Jönsson et al. 2013). The outcomes of the initiative did not yield great success due to the fact that the method is difficult

171 to operate, time consuming, cumbersome and often unavailable for purchasing. As a result, the
172 method was inconvenient for miners who are production driven. Secondly, the use of the
173 instrument incurred capital costs to miners who are impoverished and unwilling to invest on a
174 fragile and less productive product. Veiga et al. (2014) suggested that intensive cyanadation of
175 gold concentrates is the most realistic process. In contrast, cyanide is much more poisonous
176 than mercury, when considering unsafe practices that the miners are engaged in. About 909
177 miners were reported dead due to occupational exposure to cyanide in Guyana, Ghana (Veiga
178 et al. 2014). In addition, cyanide is deleterious to the environment and requires to be destroyed
179 by oxidizing it after use. This process cannot be easily adopted by miners. Moreover, the
180 method needs capital investment and production sales (Macdonald et al. 2014). In the direct
181 smelting process, the use of barox has been proven to be more effective compared to the
182 amalgam process, yielding an average recovery rate of 98.3% compared to 88% with the
183 amalgam process, at equal time and costs (Amankwah et al. 2010).

184 Greater success can be acquired by introducing a more appropriate technology that enables
185 miners to easily carry out and operate; a technology that is quick, cost-effective, accessible,
186 profitable and environmentally sound. Styles et al. (2010) is of the opinion that for any method
187 to be accepted by the artisanal mining community, it must be simple to use, easily accessible
188 and cost-efficient in a short term. There is a need to understand the socio-economic, legal and
189 environmental state of ASSGM in order to provide an appropriate and effective method that is
190 linked to a proper education, training, financial support and monitoring. Continuous
191 monitoring, training and education after the introduction of a new technology are important
192 because miners are transient. Survey studies (Styles et al. 2010; Veiga et al. 2014) have found

that ASSGM miners are willing to use alternative methods provided it is equivalent or if it outweighs the advantages of mercury use.

5. The inconsistency in estimating the population of ASSGM

ASSGM has been wide spread throughout the world for over 2000 years ago (Hilson, 2002b). Since 2006 until 2015, the estimated number of artisanal and small-scale miners worldwide has been estimated to be between 10-16 million, which in turn supports more than 100 million livelihoods (Drace et al. 2012; Saccatore et al. 2014). There is inconsistency regarding the size of the population of ASSGM. For example, Hilson and Gatsinzi (2014), mentioned that there are 10 million in the sub-Sahara Africa, while elsewhere it is reported that at least 2 million people are directly employed in sub-Saharan Africa (Weng et al. 2015). Recently, Saccatore et al. (2014) estimated that over 16 million people are involved in ASSM globally using only the hypothesis that "ASSGM population is directly proportional to the shift in gold price". There are numerous potential drivers of ASSGM which include population growth, unemployment and poverty, especially in developing countries where these factors have been increasing progressively over the past decades. In Africa for example, population have been increasing in Zimbabwe, Tanzania and Ghana at the rate of 0.62-4.36%, 1.83-2.8% and 2.07-2.19% from 2006-2014, respectively (IndexMundi 2015). Consequently, the unemployment rate has been increasing at the rate of 11.7-10.3% and 12.9-5.2% percent in Tanzania and Ghana, respectively. In Zimbabwe, the informal sector accounted for over 80-89% of employment from 2005-2013 (Saungwame et al. 2014; IndexMundi 2015). Trends of population growth and increases in unemployment rates have been experienced in South American and East Asian countries that

are also known to subsist on ASSGM. For example, population in Venezuela, Brazil and Indonesia have increased by 1.38-1.42%, 1.04-0.83% and 1.41-0.95% from 2006-2013, respectively. Their unemployment rates have been increasing by 8.9-7.9%, 9.6-5.7% and 12.5-6.6% from 2006-2013, respectively (IndexMundi 2015). The aforementioned calculated estimates on the population of miners are based on data collected from merely 58 countries out of 98 reported gold producing countries in the world (Saccatore et al. 2014). The number of ASSGM population have been underestimated and the problem is greater than what is perceived. Hence, an estimate that reflects the near accurate population of global artisanal and small scale miners is needed that is based on consistent data collected from on-field census. There are many challenges that might result in an inaccurate estimate of the number of ASSGM, and stems from the fact that the majority of miners are transient, seasonal, stay underground for a long period, operate illegally, are unregistered and have no formal appointments.

6. Socio-economic and environmental challenges caused by ASSGM

6.1. Economic challenges

ASSGM is an important economic development tool to alleviate poverty in the developing countries and contributes significantly to national revenues (Teschner 2014). ASSGM activities provide an important source of minerals by fully utilizing deposits that are not favourable to large scale mining (Castro and Sánchez 2003). ASSGM also encourages large scale mines to be more rational and efficient through competition (Shen and Gunson 2006). Poverty and lack of economic alternatives are the main drivers of the population increase in the sector (Weng et al.

2015). The increase in the price of gold in past years also account for the explanation for the recent fashion of ASSGM. The literature has shown that an inexpensive and easy mercury amalgam process is used throughout the world in countries that subsist on ASSGM, and the resulting economic effects are well documented (Styles et al. 2010; Hilson and McQuilken 2014). ASSGM is largely practiced in developing countries as it provides an important source of income (employment), particularly in areas where there are few economic alternatives. More than 25% of the world's gold production is from ASSGM (Drace et al. 2012). Despite the economic benefits brought by ASSGM on families as well as states, the resulting consequences of the activity on the environment and human health cannot be ignored. The negative effects of mercury releases and emissions have been elevated to international concern where initiatives to reduce, control and eliminate the use of mercury are encouraged. Currently, there is increasing attention given to economic conditions around ASSGM, which includes financing an awareness campaign, donating mercury free technology, and funding for education and training facilities. However, this initiative has, so far resulted in limited success because of poor communication networks which has led to improper dissemination of information. Thus, resources result in benefiting few miners and yielding less success on solving the problem of reducing, controlling and eradicating the release, emission and use of mercury by artisanal miners. Avoiding taxes and decommissioning liability costs are one of the major challenges because miners do not want to comply, hence they avoid contact with government officials. The financial support for ASSGM is also augmented by the Minamata Convention on mercury on developing countries to enable the countries to reach the set objectives.

6.2. Social challenges of ASSGM

Poverty, lack of socio-economic alternatives and seasonality of agriculture are reported to be the main drivers of people into the ASSGM (Viega et al. 2014; Oramah et al. 2015). A population of more than 16 million people directly depend on ASSGM to sustain their livelihood, and they further extend the support to more than 100 million people (Saccatore et al. 2014). The employment, income and production generated from ASSGM activities come with significant costs to the miners themselves, and to local and global community well-being. The occupational safety of miners is often compromised, the risks associated include underground tunnel failure and fire, machinery accidents, inhalation of mercury vapour and carbon monoxide. Social impacts of ASSGM include human trafficking, forced child labour, prostitution, drug usage, violence and abuse of women (Bashwira et al. 2014; ILO 1999).

There are many accidents that occur during ASSGM activities. However, most of the incidents are not reported except in the cases of death, since the activities are illegal (Shen and Gunson 2006). The International Labour Organisation estimated that fatal incidents are 6-7 times greater than in the formal mining sector (ILO 1999). Quironga cited by (Shen and Gunson 2006) outlined preliminary strategies to move against social inequality in ASSGM. These strategies include implementing alternative sustainable economic sources with the help of the government, private sector, non-governmental organisations (NGO) as facilitators and partners. The negativity of ASSGM, is that the illegal operations can encroach onto the concessions of the formal mining sector, leading to safety hazards by undermining existing workings while highly grading the deposit. Lack of knowledge and awareness about the effects of mercury on human environment health, and implementing the available alternative mercury free methods are the main social challenges faced by different countries in the world (Styles et al. 2010).

6.3. Environmental impacts of ASSGM

Mercury is used by ASSGM throughout the world, and the environmental and health effects are largely documented (Styles et al. 2010). The majority of ASSGM depends on mercury to amalgamate gold and separate it from its ores, and they are characterized by improper disposal of resulting waste (Davis 2014). Contamination of surface and groundwater due to released mercury, vapour and dust eroded from MEASSM is a major problem. As a result, significant levels of mercury have been determined in the immediate environment (soil, sediments and aquatic systems) where ASSGM operations exist (Basu et al. 2015; Cobbina et al. 2015). Once mercury is introduced into the environment, it can be eroded by wind and runoff, retained in the environment by organic matter, plants and organisms or may be emitted into the atmosphere (Lusilao et al. 2013; Xu et al. 2014). In the atmosphere, mercury can be suspended for a long period of up to 10 years and may travel over 1000 km to be deposited elsewhere. Under aerobic and anaerobic conditions, mercury can be methylated into its most toxic form, methylmercury, which can easily bioaccumulate in the food chain to mostly affect the consumers at the top of the food pyramid. Residual waste, burning of mercury and careless handling of mercury are the major contributors to environmental mercury pollution from ASSGM (Castro and Sánchez 2003). ASSGM is a significant source of mercury to the environment, contributing to about 800 t of mercury per year being released into the environment (Shen and Gunson 2006).

7. Challenges and issues on combating mercury use in ASSGM

299 Hilson and Gatsinzi (2014) have outlined the efforts made over the past decades to formalize
300 the ASSGM sector, highlighting the paradox between the government regulatory frameworks,
301 socio-economic development and environmental sustainability. A number of initiatives have
302 been put in place across the world aimed at reducing, controlling and phasing out mercury use
303 in ASSGM, particularly its releases into the environment. Governments have set regulations
304 that seek to address the social, environmental and economic aspects of the sector. However,
305 the compliance of artisanal miners is generally low as a result of lack of education, financial and
306 technological support, as well as weak governance (Bugnosen, 2000; Kambani 2003; Shen and
307 Gunson 2006). For example, Ghana and Tanzania are one of the developing countries that have
308 a long history of legalized ASSGM, and lots of interests have been generated by the
309 governments in this sector because of its socio-economic benefits. However, due to a lack of
310 necessary education, technical and financial support that encourages sustainable mining, most
311 operations are poorly managed environmentally (Crispin 2003; Jönsson et al. 2013). In Nigeria,
312 an attempt to develop ASSGM was made by the World Bank, with a financial injection of about
313 US\$10 million, however the investment yielded disappointing returns (Oramah et al. 2015).

314 A more positive example is the initiatives that have been undertaken by the Department of
315 Mining in Papua New Guinea and Chile which incorporates a proactive source of educational
316 activities and information gathering for ASSGM. This initiative has led to improvements in the
317 sector and the government has been able to develop a comprehensive development plan for
318 ASSGM (Crispin 2003; Castro and Sánchez 2003). The Papua New Guinea initiative has resulted
319 in gaining support from private sectors and NGO's from local and international communities,
320 attempting to improve the socio-economic and environmental conditions of the country which

are vital for poverty alleviation and state development. A similar intervention was undertaken by the government of China. Despite ASSGM being illegal in China, the Chinese government is intimately involved and encourages sustainable artisanal mining (Shen and Gunson 2006). The government of Mozambique initiated a scheme that promotes technologies and encourages ASSM to be established as a business by creating a miners association and this has proved to be a success (Dondeyne and Ndunguru 2014). In South Africa, Mintek Small-scale and beneficiation division has established a training school that provides ASSGM with an outcome-based theoretical and practical training, that aspire and assists with legal compliance, and have introduced “igoli technique” as an efficient method to be used by ASSGM for extracting gold from its ores (Mintek 2011).

Despite many initiatives to educate, train, reduce, control, monitor and eliminate the use of mercury in ASSGM communities, success has been limited (Drace et al. 2012). The resulting limited success is due to the number of factors that are centred on; (1) lack of a communication network, (2) failure to disseminate relevant information and technology and, (3) lack of monitoring, training and education. Several studies focused on seeking to improve the overall situation of ASSGM (Hilson 2002a; Shen and Gunson 2006; Sippl 2015). They argue that the international community has the potential to improve the sustainability in the ASSGM sector by; (1) legalizing ASSGM and implementing sector-specific legislation; (2) contributing to community development and providing increased community support; (3) providing training and educational assistance; (4) playing and expanding the role in the dissemination and transfer of skills and technology; (5) developing and implementing appropriate licensing procedures for ASSGM; (6) improving coordination among public entities responsible for the control of the

ASSGM sector, and (7) carrying out research and circulating environmentally sound mining technology. More importantly, all inclusive (public, private, NGO's, community) mining structures can provide the solutions to the implementation gaps identified (Sippl 2015; Langston 2015). Implementing these initiatives could facilitate the reduction of mercury pollution on the site. Therefore, introducing alternative technologies aimed at reducing mercury usage and release of mercury requires a far better implementation plan than policy enforcement. This could be enhanced by developing an all-inclusive communication network which takes into account all factors and challenges that are prone in the ASSGM sector.

8. Challenges and solutions on formalizing ASSGM

In African countries such as Ghana, Mali, Nigeria and Tanzania, the legal ASSGM is recognized and encouraged by the governments; however, a mining permit/lease or pass must be obtained to be recognized. The formalization is aimed at controlling the emission and release of mercury from ASSGM activities (Uka 2011; Veiga et al. 2014; Oramah et al. 2015). Furthermore, the initiative provides the opportunity to tax royalties and keep a register of miners. However, such initiatives are not acceptable to miners. This initiative has resulted in a number of failures, because artisanal miners do not want to pay tax that will not lead to immediate profits returns, go through bureaucratic protocols of obtaining mining rights, comply with the environmental laws and pay decommissioning rehabilitation costs.

Other reasons include, but are not limited to, lack of information, education and support on how to obtain the mining rights and how to improve on gold extraction methods, protect the environment and handle mercury safely. The absence of a government authority in remote

364 ASSGM areas to monitor compliance and the diversity of miners from those who are
365 mechanized to those who pan sand on river banks, makes it difficult for government officials to
366 fully monitor the operations. A properly formalized ASSGM is an intricate process for both
367 miners and the government if appropriate strategies are not developed and implemented
368 (Veiga et al. 2014). Several governments have struggled to formalize ASSGM (Hilson and
369 McQuilken 2014; Oramah et al. 2015; Davis 2014). For example, Tanzania mining Act of 2010,
370 mandate miners to use retorts while heating gold-amalgam. Hence Veiga et al. (2014) argued
371 that the regulations are not always a solution for experienced mercury usage, release and
372 emission problems. Several studies (Oramah et al. 2015; Weng et al. 2015; Sippl 2015) have
373 outlined commonalities that result in successful ASSGM mining. These successes have been
374 possible because of involvement of the government, NGOs, private sector and the communities
375 where the ASSGM activity operates. Figure 1 illustrates a proposed communication hierarchy
376 structure (top down-bottom up approach) that can be effectively applied to promote
377 sustainable ASSGM. It has been developed from a number of successful and unsuccessful
378 initiatives on combating mercury use by ASSGM, particularly from the work of Sippl (2015). The
379 proposed structure places emphasis on communication being facilitated in a harmonized
380 manner amongst the interested and affected parties. A top down-bottom up approach is a
381 means of communication that is integral for effectively formalizing, reducing and controlling the
382 use of mercury, release and emission by ASSGM. There is a growing consensus that the
383 community must be included in the management of mining activities in order to catalyze broad-
384 based economic development whilst simultaneously achieving maximum social and economic
385 benefits (Langston et al. 2015). If the communication is between the government and ASSGM,

miners may by-pass the rules, however, if the miners, community leaders and private sectors are involved together equally with the government by-passing of the rules by miners can be avoided. The government and private sectors should provide aid and support to the communities where mining is taking place, assist miners with the process of attaining the mining rights, training, education and appropriate technology. The private sector can also buy gold from the miners on behalf of the government and could be tasked to keep register and provide technical assistance to artisanal miners (Dondeyne and Ndinguru 2014). Langston et al. (2015) is of the opinion that an approach incorporating social, political, economic and environmental issues in a decentralized, but geographically focused management arrangement will help to address the sense of illegality that runs through the ASSGM sector. The top down-bottom up approach will enhance the understanding of demographics, ethical background, the community interest and the level of education that enhance an appropriate technology, management measures and monitoring the sector to achieve sustainable ASSGM.

Kambani (2003) suggested that, the challenge on institutions that are responsible for managing ASSGM efficiently are unable to carry out regulatory and monitoring mandates due to inadequate resources. The regulatory challenge faced by poverty enshrined ASSGM is the bureaucracy and embedded costs to carry out environmental impact assessment and management plans before a mining lease or exploration right is granted. These bureaucratic and costly processes are difficult to artisanal miners when considering their background. Many developing countries have introduced laws and regulations for their perspective ASSGM sector, but these have not necessarily helped on improving the social and environmental problems associated with ASSGM (Bugnosn 2000). In view of the requirements of the Minamata

408 Convention on mercury, if clear and proper communication guidelines are not put in place, the
409 future of the Minamata Convention on mercury looks grim. Sippl (2015) argues that many
410 signatories of the treaty have ASSGM regulations in place but lack the will and ability to enforce
411 them. Because enforcing regulations on ASSGM alone have proven ineffective in curbing
412 mercury pollution, an effective introduction of new technology must be accompanied by a
413 comprehensive approach (Macdonald et al. 2014).

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414

415 Figure 1. A proposed communication hierarchy to enhance the implementation of the

416 Minamata Convention on mercury.

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418

9. Discussion

Despite the negative challenges and issues associated with ASSGM, the activity has proven to be a viable economic source that can potentially support rural development and profits to the government (Oramah et al. 2015). However, the states rarely invest on ASSGM development (Shen and Gunson 2006). Several studies argue that the contribution of ASSGM may outweigh its negative impacts, especially if the government put forth greater effort to regulate, guide and encourage the development of the sector and create a sound environment for the operations. Shen and Gunson (2006) are of the opinion that ASSGM is a corner-stone of future economic development, particularly for disadvantaged communities. This is more relevant in the current increase in unemployment rate in countries such as South Africa, where the unemployment rate is currently at 25.5%. An appropriate system of laws and regulations, and suitable institutional structures for the administration of ASSGM are important requirements for the effective management of the sector. Government, regional and international bodies must play an expanded role in disseminating important information, technology and economic support. The question that remains unanswered is the kind and structures of legislations that will efficiently regulate ASSGM.

The present review has provided a reliable and self-proven communication structure that can enhance the implementation of the requirements of Minamata Convention on mercury. It is certain that ASSGM will continue to play an important role in the development of any country. Based on the international literature, ASSGM has long existed and cannot be expected to effectively regulate itself and mitigate its own negative impacts. Regulating the sector does not

mean destroying it, therefore, a sound and sustainable ASSGM need to be enhanced (Shen and Gunson 2006). However, if properly managed, the sector can bring tangible, but short term benefits to the communities involved and this can outweigh the health cost incurred, environmental pollution, waste of natural resources and market distortions.

Overall, the social and environmental issue of ASSGM tend to outweigh the economic benefits. Lack of knowledge and awareness about the effects of mercury on human health, environmental and alternative mercury-free methods are the main challenges faced by the majority of countries that subsist on ASSM within their territory. This is exacerbated by shortage of financial support, alternative economic activities, and high unemployment rates. In contrast, several funded initiatives have been undertaken to address the aforementioned challenges in ASSGM, and the majority were unsuccessful. However, the benefits support more than 100 million people as a means of poverty alleviation.

The Minamata Convention on mercury remains an important tool for protecting human health and the environment from anthropogenic mercury pollution. Continuous attempts must be made to address negative impacts while optimizing the benefits. The top down-bottom up approach is an instrumental approach for effective management of ASSGM and for achieving the objectives of the Minamata Convention on mercury in a timely manner. The success depends on the way technology, training, education and financial support is being introduced. This approach will certainly drive the initiatives on combating mercury use and changing the perception on ASSGM.

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