An Integrated Assessment of Artisanal and Small-Scale Gold Mining in Ghana: Final Report

GRAHAM
SUSTAINABILITY INSTITUTE
UNIVERSITY OF MICHIGAN

GMIA Ghana-Michigan Gold Mining Integrated Assessment

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Appendices

1. Executive Summary

Artisanal and small-scale gold mining (ASGM) has proliferated worldwide largely because of powerful economic forces and widespread poverty. Globally, more than 100 million people are estimated to live in small-scale mining communities. There is growing evidence that ASGM activities have profound consequences for human and ecological health and well-being.

Since 2009, our team from the University of Michigan has conducted research in Ghana on ASGM. Our experiences and findings have shown that narrowly-focused, single-discipline interventions to improve health, ecological outcomes, or social and economic well-being in ASGM communities have proven unsustainable owing to technological, institutional, and/or behavioral barriers. Because of the complex nature of the causes and consequences of ASGM, an interdisciplinary framework is needed. The Integrated Assessment (IA) method provides such a framework for examining and tackling "wicked" problems such as ASGM. Over the past three years, involving a diverse team of 30+ researchers and stakeholders, we have used this framework to document the causes, consequences, status, and trends of ASGM in Ghana, and to develop response options based on data from across disciplines.

Ghana is in a unique position relative to other countries that host ASGM. It is among the largest producers of gold in the world, and gold mining has a long, rich history that predates its contemporary borders by nearly 1000 years. Among developing countries facing expanding ASGM, it arguably has the strongest network of active in-country researchers. In light of the United Nations Environment Program's (UNEP) recent global treaty on mercury pollution, the Minamata Convention, which has entire articles devoted to the ASGM sector, countries with such expertise available on ASGM are well-positioned to be at the forefront of solutions to ASGM.

Using the IA framework, we analyzed public health, ecological, social science, and economic data to address the following over-arching policy-relevant question: *What are the causes, consequences, and correctives of small-scale gold mining in Ghana?* More specifically: *What alternatives are available in resource-limited settings in Ghana that allow for gold-mining to occur in a manner that maintains ecological health and human health without hindering near- and long-term economic prosperity?* The ultimate goal of our partnership was to co-develop with stakeholders solutions to problems associated with ASGM in Ghana that are inexpensive, sustainable, low-tech, health-promoting, and socially acceptable.

The IA was conducted by three technical work groups (natural sciences, human health, and social sciences and economics) comprising mainly Ghanaian researchers hailing from academia, government, and NGOs, as well as several partners from North America. Each workgroup was advised by at least one independent, international expert. A project manager (Long) and two principal investigators (Basu, Renne) oversaw the entire project. In each year, subsets of the team met for annual in-person workshops in Ghana, and between meetings the team maintained communication via email, conference calls, and other online tools. In Year #1, group membership was finalized and tasks delegated and in Year #2, gathered data were synthesized and presented. In Year #3, refined data were synthesized, presented, and published, and workgroup members developed and evaluated a set of response options to ASGM in Ghana based on these data. The findings were also shared with additional relevant stakeholders, who in turn evaluated the proposed response options.

The development and evaluation of these response options represents one major outcome of the IA. The six response options ultimately recommended by the IA are:

- that a national framework for policy and planning implementation be established (i.e., taskforces, workgroups) that considers stakeholder input.
- that registration of small-scale miners be increased by improving the process by, for example, reducing or eliminating fees and localizing registration.
- that ministries, local governments, and District Assemblies promote diversification of economic opportunities.
- that there be public and private support for education with ASG miners on ecological and human health risks, mercury and metals, mercury reduction strategies and business practices.
- that the royalties from the proceeds of mining be placed into a central account and directed towards improving health and environment of ASGM communities.
- that universities, the EPA, and the Minerals Commission explore and implement high-yield mercury free alternatives.

A second major outcome is a series of nearly 25 publications, most of which are in a special journal edition in the International Journal of Environmental Research and Public Health (IJERPH; http://www.mdpi.com/journal/ijerph/special_issues/asgm) that will feature 17 papers written by members of our research team. Among these are three discipline-specific synthesis papers that summarize extant and emerging data within each of the aforementioned workgroup domains (natural sciences, human health, and social sciences/economics). The third major outcome of this project is the strengthened network of researchers, policymakers, government officials, NGOs, and other stakeholders that this project has engendered. The relationships built throughout this project, as well as the training and research opportunities it has facilitated, will ultimately contribute to Ghana's ability to address ASGM in a way that is safe for human health and the environment and enables economic growth.

2. Introduction

2.1. Background

ASGM activities are increasing worldwide due to the rising price of gold, the proliferation of larger mines, and widespread poverty. Globally, approximately 20 million people work directly in ASM, and 80–100 million are dependent on it for their livelihood [1]. Gold from small-scale mines may represent 20-30% of the world's output [2].

West Africa, particularly Ghana, is one of the world's most important gold mining regions. From antiquity, through the colonial period and up to today, gold mining has been an integral part of Ghanaian history (Appendix 1a.). Gold has been mined in Ghana for over 1000 years [3]. By the 6th and 7th century AD Ghana had already emerged as one of the largest gold producers in the world, supplying the majority of gold to the Arab world via Saharan trade routes [4]. Mining was mostly conducted in the Akan states of Asante, Denkyira, Akyem and Wassa, with gold emerging as the primary method of payment for taxes and tribute [5]. Mining relied on a number of techniques ranging from panning to shallow pit and deep shaft mining, similar to operations today [5]. While for most of its history the main market for Ghanaian gold was the Middle East, in the late 15th century focus it shifted west as European merchants became increasingly involved in the Ghanaian gold trade [3]. At first the industry was natively run, but by the late 19th century efforts were made by the colonial government to systematically exclude

Ghanaians in the interest of European capital [3,5]. By 1930, all mining concessions were in European hands and the industry was suffering a serious labor crisis as Ghanaians refused to work in the mines [5]. With Independence in 1957, the mining industry was nationalized so as to overcome foreign dependency and fuel national development. However, by the late 1970's the industry, like much of the Ghanaian economy, was falling apart. Beginning in 1983, the government, upon the advice of the IMF, implemented a series of neo-liberal reforms, including the privatization of state owned mining companies and the opening up of the country to foreign investment [6]. The effects of these structural adjustment programs have been twofold: 1) Dramatically increase the investment in the Ghanaian mining industry by foreign multi-nationals and 2) further impoverish the majority of Ghanaians leading to a rise in illegal mining activities [6]. Partly in response, the government legalized small-scale mining in 1989 but most miners still operate informally without government oversight.

Currently Ghana is the second largest gold producer in Africa, yet divisions remain between a large-scale sector dominated by foreign companies and a mostly informal small-scale sector which employs up to a million Ghanaians [7]. As governments continue to court foreign companies while failing to meet the needs of small-scale miners, the conflicts between the two will continue [8]. For the near future at least it appears that gold mining will remain an important aspect of Ghanaian society. In 2012, gold accounted for 43% of the country's national exports [9]. ASGM accounted for 10.5% of Ghana's national gold production and employed 0.5–1 million people as of 2010 [10,11]. Gold production from ASGM in Ghana rose 43% from 2011–12 [12]. Approximately 70% of ASGM in Ghana is estimated to occur illegally, though specific numbers are hard to determine. Such illegal operations are not registered and licensed under the provisions of the Small-Scale Gold Mining Act of 1999 [13].

Though variations exist across the globe and even within Ghana, the basic steps of the ASGM process (excavation, crushing/grinding, sifting, washing/sluicing, amalgamation, and burning) are similar everywhere (Appendix 1b). At the start of the ASGM process the gold-containing ore is excavated. This can be accomplished using a variety of methods, including panning in streams, surface excavation with simple tools, shallow digging, or tunneling, which may involve shovels, picks, heavy motorized equipment, or explosives. Miners then crush the excavated ore manually using a large mortar and pestle, or using gas-powered grinding machines, or both methods. Often the ore is ground multiple times to achieve a fine powder. In the next stage of the process, sifting, which is usually performed by women, the pulverized ore is sifted through a cloth suspended over a basin. The larger ore particles that do not pass through in the cloth are then re-ground using machinery and re-sifted.

During the washing phase, miners mix the finely powdered ore with water and gently wash it down a carpeted "sluicing" ramp. Dense gold-containing particles are trapped in the carpet and less dense components of the ore are washed away down the ramp. The gold-containing ore particles are then prepared for amalgamation with mercury by adding them to a shallow pan with water. The pan is swirled by hand, effectively centrifuging the ore and further separating the gold from the ore. The gold, which can be visible at this stage, is then mixed in small volumes with mercury. The resulting gold-mercury amalgam forms a ball that miners then heat with a blowtorch, small fire, or other heat source, which causes the mercury to volatilize. Left behind is a nugget of concentrated gold. Dealers usually purchase the gold at this stage, and take it to refineries where the mercury amalgamation process is repeated before the gold is deemed pure enough for export.

2.2. Existing Research

Our pilot grant, which funded fieldwork in the summer of 2011, and led up to the IA grant, yielded an interdisciplinary paper on the different ways that water is valued in ASGM communities [14]. This paper illustrated the complexity of problems related to ASGM, health, sustainability, culture, and economics by comparing community valuations of water in the gold mining community with the water's "chemical values," i.e., concentrations of toxic metals and bacteria. The study revealed that because of its use of water and proximity to water sources, mining creates problems for availability of potable drinking water, but also creates opportunities for new economic enterprises centered around water (e.g., water vending, bath houses), and new methods of water treatment (e.g., use of disinfectants in bath house water). It also revealed that community ideas about water safety sometimes coincided and sometimes conflicted with laboratory evaluations of its safety. For example, some community members used mine pit water for bathing or brewing alcoholic beverages, despite others' reports that such water was contaminated with mine waste and human waste, and our findings that it contained elevated levels of several toxic heavy metals [14].

Other data from the pilot grant were analyzed during the IA grant phase and yielded information about demographics and other health-related factors [15], injuries [16], mercury contamination and exposure [17], possible health outcomes related to mercury exposure [18], malaria risk [19], and pulmonary health [20]. These data have contributed immensely to understudied aspects of ecological and human health in ASGM areas and in some cases are among the first studies in Ghana to provide data on their respective topics, and in some cases, the first in sub-Saharan Africa.

In the IA process, all currently available evidence concerning ASGM in Ghana, including that from our pilot study and emerging studies, was reviewed. To the best of our ability, all evidence from Ghana was reviewed, which includes both peer-reviewed and non-refereed sources, and both published and non-published sources. Evidence from other regions of the world was incorporated as needed. Data are emerging, however, that supports concerns for ASGM's effects on public health, the environment, society, and certain segments of the economy.

Our team's findings have shown that in the domain of public health [21] concerns about high exposures to mercury are well-founded, with not only miners but also community members being affected. There is also moderate certainty that miners and community members may be

exposed to other heavy metals, such as cadmium, lead, and arsenic, likely mobilized during the mining process. Occupational injuries, which have been reported upon extensively in the Ghanaian media, are also prevalent in ASGM sites according to recent research by our team (i.e., results from three new research papers). Noise exposure, which in addition to causing hearing loss may contribute to stress and cardiovascular and mental health problems, is being documented in ASGM communities at levels above recommended guidelines. There is also evidence that there may be differences between ASGM communities and other communities in Ghana in terms of psychosocial health, nutrition, cardiovascular and respiratory health, sexual health, and
water and sanitation.

Ecological consequences of ASGM are also increasingly well-documented [22], though variation abounds across measures and sites, and data gaps still necessitate some speculation. Our team reviewed dozens of studies on mercury and other heavy metals in environmental media in Ghana. Mercury contamination is high and widespread in sediment, with 64% of sediment samples exceeding guideline values, but few samples exceeded guideline values in water or in soil. Arsenic, cadmium, and lead contamination is another concern; water samples exceeded guideline values in 67%, 17%, and 24% of water samples, respectively. Some water samples studied also exceeded guidelines for acidity, turbidity, and nitrates. Though it is difficult to determine the precise contribution of ASGM to deforestation, loss of forest cover is visible in ASGM areas, likely due in some part to mining activity. It is expected that ASGM contributes to biodiversity loss through destruction and degradation of habitat. ASGM's contribution to other ecological issues such as legacy contamination and climate change are as of yet poorly understood, but plausible.

Social and economic evidence [23] suggests that at the microeconomic level, "push" factors that aim at meeting livelihood goals are among the primary reasons that most people begin ASGM. The income generated from ASGM represents an important source of livelihood for both mining communities and distal communities, providing income for otherwise impoverished farmers and stimulating small business growth. At the macroeconomic level, ASGM in Ghana contributes a significant portion of the Ghanaian economy. However, despite the potential economic benefits of ASGM, miners can become trapped in poverty by low productivity and debt, which limits their options for other economic activity. Miners are also at a large competitive disadvantage to large-scale, industrial, often foreign-operated mining companies, whose access to land and technology outstrips that of ASG miners. Furthermore, additional issues such as land tenure, social stability, mining regulation, mine taxation, and environmental degradation bring into question the long-term sustainability of ASGM as a livelihood option for poor Ghanaians.

It is clear that the issues surrounding ASGM in Ghana are complex and multi-faceted, and cross disciplinary boundaries. A multidisciplinary approach is therefore needed. To tackle this "wicked" problem, our team sought to integrate data from all relevant domains to answer the following over-arching policy-relevant question: *What are the causes, consequences and correctives of small-scale gold mining in Ghana?* More specifically: *What alternatives are available in resource-limited settings in Ghana that allow for gold-mining to occur in a manner that is safe for environmental health and human health without affecting near- and long-term economic prosperity?*

2.3. Overview of Research Team

The IA project has its origins in the UM undergraduate course Maternal/Child Health, the Environment, and Pollution in Africa (DAAS 409/ANTHCUL408) taught by PI Renne, which historically had taken a field trip to Africa to study maternal, child, and environmental health issues. In advance of one such trip, PI-Renne visited Ghana in February 2008 and met with Mr. Simon Attebiya (Planning and Policy Officer, Minerals Commission-Ghana), Prof. T.M. Akabzaa (Dept. of Geology, University of Ghana-Legon), and Mr. Robert Boarzor Tampoare (Secretary, local Small Scale Miners Association-Bolgatanga) and others involved with small-scale gold mining. From these conversations emerged clear research needs at both the local and national levels. Mr. Attebiya observed that there had been little documentation of health hazards associated with small-scale gold mining, such as silicosis and upper respiratory tract infections due to the inhalation of pulverized rock, and mercury poisoning due to the processing/burning of amalgam. There was minimal understanding of the impact of mining activities on water resources. Furthermore, the social consequences of the gold mining "boom" in mining areas, especially newer mining areas in the North, were poorly understood. It also became clear that in general, there was a dearth of data mining in northern Ghana, as most studies on ASGM to date had come from southern Ghana.

In May 2009, thirteen students in PI Renne's class traveled to Ghana, and of those, five stayed in the Upper East Region of Ghana for the summer to conduct research [24]. In March 2010, PIs Renne and Basu visited Ghana to meet with academic partners, government officials, and miners regarding the project. In June 2010, another group of eight undergraduate students participating in the DAAS study abroad program and two graduate students from the UM School of Public Health and UM's Anthropology Department and School of Social Work spent six weeks conducting follow-up research in the Upper East, during which they collected ecological samples and biological samples from community members and conducted surveys focusing on maternal and child health.

A one-year pilot grant in 2011 from the UM Center for Global Health and the Graham Sustainability Institute enabled the project to expand. Additional funds were dedicated from an NIH-Fogarty Signatures Innovation grant, which focused on training of public health professionals. Additional investigators from U-M School of Public Health (Profs Tom Robins and Mark Wilson) were engaged in 2011. This team, in addition to six UM students from Public Health and Anthropology/Social Work, visited study sites, met collaborators, and expanded networks in the country during a May 2011 visit (Appendix 2). The six students stayed in Ghana for two months for fieldwork to document water-related issues (e.g., economics of water, quantification of biological and chemical agents in water, sanitation options, malaria), characterize understudied health outcomes (i.e., hypertension; lung function, injuries) in relation to mining activities and engage a nearby agricultural community, which allowed an unprecedented opportunity to compare agricultural and mining communities.

In May 2012, upon receipt of the IA grant from the Graham Sustainability Institute, our team initiated the IA process. Through the investigators' networks, four fellow project leaders, all researchers from government and academia in Ghana, were recruited (Edith Clarke, Samuel Obiri, Peter Agyei-Baffour, and Emmanuel Tenkorang). At least one North American leader was paired with at least one leader from Ghana to head one of four technical workgroups (Human Health, Natural Sciences, Economics, and Social Sciences) which were later condensed into three discipline-specific workgroups (Human Health, Natural Sciences, and Social Sciences/Economics). These co-leaders identified additional individuals through their networks to be invited to join the workgroups, resulting in a team of 4-6 members per workgroup, headed by 2-3 North American and Ghanaian co-leaders (Appendix 3). The project was overseen by two PIs (later joined by third PI Neitzel), managed by a project manager, Rachel Long, and later advised by external experts with international experience in ASGM issues.

2.4. Overview of IA Activities

Upon formation of the core group of co-leaders team, in early Year 1 (Aug 2012) (Appendix 4), technical workgroup leaders, the PIs, and the project manager met in Accra at the University of Ghana-Legon Campus for a 2-day planning meeting (Meeting #1). Group leaders finalized team membership (see Appendix 3), defined group-specific policy-relevant questions under the umbrella of our overall research question (Appendix 5), identified data sources, and discussed potential hurdles. Explicit timelines were set (Appendix 4). Strategies to engage workgroup members and task delegation were discussed. An evaluation of the meeting and of the IA process to date was conducted (Appendix 6a).

In Year 2, a two-day workshop (Meeting #2) was held at UG-Legon for all workgroup members (co-leaders and research team members, with 22 attendees in total) in Feb-Mar 2013. Workgroup members had about six months to prepare datasets (their own research and/or extant data) for presentation. The intent was to start filling in data gaps in Ghana with research from our team, while aggregating existing data. Twenty out of 22 attendees made a total of 22 presentations on research contributions to the IA (Appendix 7). During the meeting, each workgroup generated a written document covering topics discussed at the meeting such as available data, plans for Meeting #3, stakeholders to engage in the process, and project outputs. Meeting #2 attendees evaluated the value and legitimacy of Meeting #2 and the IA process (Appendix 6b).

Also in Year 2, several complimentary activities enhanced the IA process. An undergraduate research assistant, Rebecca Brewster, contributed research on mining injuries and on Chinese-Ghanaian relations in ASGM. PI Neitzel led new fieldwork in the Upper East Region to better document occupational health risks such as injury, noise exposure, and stress [16,25]. Three researchers, Dr. Eric Odei, Dr. Benedict Calys-Tagoe, and Dr. Lauretta Ovadje (Human Health Workgroup members) accepted one-year post-doctoral fellowships at UM as part of the Ghana-UM PARTNER II grant (sponsored by the Fogarty International Center in the National Institute of Health, and of which Tom Robins, IA Human Health workgroup leader, is PI and IA PI Nil Basu is a Co-Investigator). A mentor from Ghana, Dr. Edith Clarke (Director, Occupational and Environmental Health, Ghana Health Service; Co-leader of Human Health Workgroup) joined the post-docs. As the goal of the grant was to strengthen interdisciplinary occupational and environmental health research capacity at UM and in Ghana, and theme of the PARNTER II grant was small-scale gold mining, the post-docs contributed their research efforts during their year-long training to the IA.

In addition, PI Nil Basu, Co-I Tom Robins, and Project Manager Rachel Long attended workshops and meetings April 8-10, 2013 in Accra as part of the GEOHealth grant (NIH Fogarty grant; Nil and Tom are Co-PIs). GEOHealth aims to build upon existing occupational and environmental health research and training collaborations between institutions in Ghana and UM in order to enhance capacity for research activities that address key national occupational and environmental health priorities and policies. Finally, PI Elisha Renne led a study abroad project in May-June 2014 to work with women small-scale gold miners and UM/UG students to initiate a neem oil processing project in Nangodi, UER, Ghana, in response to suggestions made at the April 2013 UG-Legon workshop The abundance of neem trees (*Azadirachta indica*) in the area presented the opportunity to develop neem-related products (oil, soap, insecticide) as an alternative to gold mining for small-scale gold mining by women miners.

During Year 3, a three-day workshop (Meeting #3) was held at UG-Legon for all workgroup members as well as four external advisors (Appendix 3) during April 28-30, 2014. During the gap since Meeting #2, workgroups wrote discipline-specific reports detailing the status and trends, causes, consequences of ASGM. Teams also developed response options to ASGM issues in Ghana (Appendix 8). At Meeting #3 teams had near-complete (75% expected) versions of their synthesis reports ready for brief oral presentation to the broader group. The bulk of the meeting focused on refining and evaluating the response options developed in the reports. Response options were discussed and evaluated via two rounds of polling based on the Delphi technique. The six response options with the most favorable evaluations based on several metrics of the Delphi poll were:

- that a national framework for policy and planning implementation be established (i.e., taskforces, workgroups) that considers stakeholder input.
- that registration of small-scale miners be increased by improving the process by, for example, reducing or eliminating fees and localizing registration.
- that ministries, local governments, and District Assemblies promote diversification of economic opportunities.

- that there be public and private support for education with ASG miners on ecological and human health risks, mercury and metals, mercury reduction strategies and business practices.
- that the royalties from the proceeds of mining be placed into a central account and directed towards improving health and environment of ASGM communities.
- that universities, the EPA, and the Minerals Commission explore and implement high-yield mercury free alternatives.

In to the aforementioned activities, the international advisers and several other team members visited mining sites in Tarkwa before the meeting to see first-hand on-the-ground mining conditions in southern Ghana. This meeting was also evaluated by all attendees (Appendix 6c).

During Year 3, the team dedicated most of its efforts to finishing the three synthesis reports and other manuscripts. Allyson Green, who contributed to the project as an MS student, was hired to help edit and finalize reports, manuscripts, and supplementary materials. Two UROP students at UM, Austin Waara and Margaret Goelz, and Sean Phipps, a student working with Nil Basu at McGill University, also contributed to the project in 2014 (Appendix 2).

In the final year of the project, a subset of the larger team planned a dissemination event to engage policy makers and other stakeholders to both 1) share our findings and 2) solicit feedback on the response options the team had developed. A meeting was convened April 20-21, 2015 at the Mensvic Hotel in Accra, Ghana, of relevant stakeholders representing local and national government, academia, NGOs, miners' associations, and other organizations (Appendix 9). Key team members and allies, including Edith Clarke in the Ghana Health Service, Dr. Vincent Nartey of the Ghana EPA Board, Dr. George Owusu Essegbey, Director of the Science and Technology Policy Research Institute (STEPRI), and Susan Keane of the Natural Resources Defense Council were critical in this effort. In the year post-Meeting #3, workgroup members also worked to finalize individual and group synthesis manuscripts for peer-review (Appendix 10). Throughout the project, presentations at local and international conferences were made to help disseminate findings and interact with the global network of researchers engaged in ASGM research (Appendix 11).

3. Analysis of Response Options

3.1. Status and Trends, Causes and Consequences

This section describes the status, trends, causes, and consequences of issues pertaining to ASGM in Ghana within and across the three domains of our IA: human health, natural sciences, and social sciences/economics. Each section is prefaced with a statement about the level of certainty regarding each topic's relationship with ASGM, which is based on the availability of scientific data on the subject, plausibility of association, strength of association, and the consistency of the findings.

The information that follows is derived from the three discipline-specific workgroup reports on the status, trends, causes, and consequences of ASGM in Ghana [22,23,21]. These reports are the product of nearly three years of research by our IA team, as detailed in our project timeline (Appendix 4). Each report was co-written by a discipline specific workgroup composed of experts from Ghana and North America, as well as advisers with international experience in ASGM, and were submitted to the International Journal on Environmental Research and Public Health and subjected to the peer review process before publication.

3.1.1. Human Health

Mercury

Certainty level: High (a number of scientific publications; plausibility, strength of association, consistency of findings)

Both ASGM miners and community members across Ghana are exposed to high, and potentially dangerous, levels of mercury. Though some studies on mercury exposure due to ASGM lack adequate technical credibility, (e.g., used inappropriate or inadequate surveys and sampling techniques), mercury use has been associated with contamination of air, water, soil, sediments, and foodstuffs at a number of sites in Ghana. As a result, biomarker studies have shown that human exposure to mercury contamination is prevalent in ASGM communities. Excessive mercury exposure is known to cause a number of adverse health effects. Evidence from Ghana linking mercury exposure to health effects is limited, but health consequences are expected based on the literature from other countries. Spatial trends in mercury exposure are difficult to assess, since most data from Ghana come from only a few key mining areas (e.g., Tarkwa and Obuasi) and less often in comparison areas including the general population. Very few studies have been conducted in northern Ghana, as most data comes from the south. It is likewise difficult to determine temporal trends, as most studies on mercury in Ghana have only been conducted in the last five to ten years. It is also important to note that even within a given mine site there exists considerable spatial and temporal variability in mercury exposures [26].

Other Heavy Metals

Certainty level: Moderate (some scientific publications; plausibility, strength of association, consistency of findings)

Both ASGM miners and community members across Ghana are likely exposed to high, and potentially dangerous, levels of toxic metals such as arsenic and cadmium. Several steps in the mining process (e.g., excavating and crushing ore) facilitate the release of toxic metals into the environment (Appendix 1f). Heavy metals contamination has been documented in a number of sites in Ghana and summarized in the Natural Sciences review published by our team [27], and some biomarker studies in miners and ASGM community members in Ghana show high exposures. As with data on mercury, data on non-mercury heavy metals in environmental and human samples tend to be focused in southwest Ghana, leaving a knowledge gap of the status of heavy metals pollution in mining areas in northern Ghana.

Occupational Injuries

Certainty level: Moderate (high plausibility and a number of anecdotes, but scientific peer-review evidence is still limited despite two additional studies performed as part of the current IA)

Limited scientific studies and some newspaper articles have documented accidents and injuries in Ghanaian ASGM communities [16,21,28,29]. Plausibility of such events is high given that health and safety issues do not receive adequate support in ASGM mines (e.g., workers are often not provided with appropriate PPE), the mining conditions are unsafe (e.g., old abandoned concessions, weak geologic formations), and there is only rudimentary training and technical expertise amongst miners. Plausibility of anecdotal information and media reports is supported by a large body of evidence of high rates of injuries and fatalities among miners in other countries [30–34]. It is possible that both active miners and ASGM community members may be affected by this important source of morbidity and mortality, though data on accidents and injuries among community members are currently not available.

Noise Exposure

Certainty level: Moderate (high plausibility but few studies)

An enormous body of evidence links occupational noise exposure to hearing loss [35], and it is likely that noise levels in ASGM operations are sufficient to produce noise-induced hearing loss (NIHL), though it is uncertain whether the existing noise measurement data in selected ASGM sites can be generalized to all ASGM sites in Ghana. There is also moderate certainty (high plausibility but few studies) that NIHL is common among ASGM miners, given previous analyses of noise exposures and NIHL in large-scale mining operations in higher income countries, where high noise exposures and NIHL are common [36]. Though non-auditory health effects have been associated with noise exposure in other populations [35], there are insufficient data available in ASGM sites to assess the relationship between ASGM noise and non-auditory health effects.

Other (Psychosocial Health; Nutrition; Cardiovascular and Respiratory Health; Sexual Health; Water, Sanitation, and Infectious Diseases)

Certainty level: Data limited

As noted in the Social Sciences and Economics report by our team [23], ASGM communities can become thriving economic centres with complementary enterprises [37], but the associated population growth can strain resources and many ASGM communities remain without adequate infrastructure and health services. Poverty and unsanitary living conditions may lead to psychosocial stress, inadequate nutrition, infectious disease, and untreated chronic conditions. Furthermore, tensions and conflict within communities can add to stress while violence brings a risk of injuries and fatalities. The lack of accessible healthcare in many communities compounds these risks.

The association between psychosocial stress and adverse health outcomes is well established: cardiovascular disease, acute myocardial infarction, inflammation, hypertension, and immune dysregulation, among many other illnesses, have been linked with chronic psychosocial stress, which can be related to work, home life, and socioeconomic status [38–43]. While evidence of physical health risks of ASGM are increasingly well-documented [21,44–46], studies on stress in ASGM communities are uncommon. Several studies [25,44] have found that community members list stress as one of many social vulnerabilities they face and have shown patterns in quantitative biomarker measurements consistent with high stress.

Studies have reported that food insecurity is the top concern for ASGM community members [25,44]. In addition to concerns about nutritional intake and food insecurity, food safety can be a health concern in ASGM communities, as fish and other edible food items from mining areas have been found to contain mercury and other heavy metals that likely entered the environment because of mining practices [22]. Studies from Ghana and elsewhere have shown high levels of mercury in the hair of miners and community members, suggesting that mercury exposure may be occurring through diet [47].

Though respiratory health of ASG miners has not been well-documented, evidence from large-scale miners suggests that this may be an area of concern in ASGM communities. Biomass cooking smoke and respirable crystalline silica in ore are major exposures of concern. Respirable crystalline silica may exceed 30% crystalline silica in some gold ore dust [48].

There is a growing concern regarding cardiovascular health across Ghana as the prevalence of hypertension increases [49]: in 1973, hypertension was estimated to be prevalent in 4.5% of participants over 16 years from rural Ghanaian villages[50], but in 2010 was estimated to be 20% in rural areas [49]. Exposures and lifestyle factors from ASGM may heighten these risks. Noise is associated with coronary heart disease and hypertension [51]. Heavy metals, such as arsenic and mercury have been associated with adverse cardiovascular outcomes [52–54]. Hair and blood mercury, which represent methylmercury exposure, have been associated with increases in systolic and diastolic blood pressure [55–58], and slightly elevated exposures have been associated with decreases in systolic blood pressure[57,59,60]. Very high exposures have been associated with increases in systolic and diastolic blood pressure [61]. A study of ASGM community members from the Talensi District in the Upper East Region found no significant associations between hair and urinary mercury with blood pressure, but the data did suggest a non-linear relationship of urinary mercury and blood pressure [18].

Because of sociocultural and socioeconomic factors described in the Social Sciences and Economics review by our team [23], ASGM communities may be particularly vulnerable to HIV/AIDS and other sexually transmitted infections (STIs) [62].There is some evidence of elevated rates of sex work and of sexually transmitted infections in ASGM communities in Ghana [63], [64–66]. Mining communities are predominantly composed of males with disposable income, and economic factors such as underemployment may encourage women to participate in sex work in exchange for money or for jobs in ASGM [63,65,66]. Women may thus be particularly susceptible to STIs given the inadequate access to sex education, healthcare and family planning services in many ASGM communities, and the social stigmas surrounding sex and contraceptive use [63]. Women in ASGM sites in Ghana also face the risk of sexual violence, and have reported verbal and physical sexual harassment and forced sexual intercourse with men [63].

There may be increased risk of infectious diseases in ASGM communities due to lack of sanitation facilities and safe drinking water sources [67,68]. Samples from drinking water sources in ASGM communities have tested positive for elevated concentrations of heavy metals and for coliform bacteria, which indicate possible fecal contamination [14]. Un-reclaimed mine pits reportedly fill with water to create additional mosquito breeding grounds, which may increase the transmission of malaria [69]. In Ghana, a spatial association between endemic buruli ulcer communities and mining activities, which raises speculation that ASGM may be a risk factor for the disease. In one district in Ghana, distance to gold-mining sites has indeed been associated with a higher prevalence of buruli ulcer [70].

3.1.2. Natural Sciences

Mercury Contamination

Certainty level: High (a number of scientific publications; plausibility; strength of association; consistency of findings)

Numerous studies focus on environmental mercury contamination throughout Ghana. Mercury has been measured in many species of fish, foodstuffs, plants, sediment, soil, mining tailings, and water. Most studies on mercury contamination in Ghana, however, have been undertaken in southwest Ghana. While this is the area with the most ASGM activity, ASGM occurs throughout Ghana, and northern Ghana in particular has been under-studied. It is difficult to assess temporal and spatial trends, as studies have not been repeated at individual sites and have only occurred in the past twenty years. Though no studies, to our knowledge, have linked mercury exposure with adverse effects in Ghanaian fish and wildlife, studies from around the world give high certainty that currently observed mercury levels in Ghana may be harmful to the health of individuals and populations.

Other Heavy Metals

Certainty level: Moderate (some scientific publications; plausibility, strength of association, consistency of findings)

There is increasing evidence that ASGM activities across Ghana are releasing high, and potentially dangerous, levels of toxic metals such as arsenic and lead. It is posited that several steps in the mining process (e.g., excavating and crushing ore) facilitate the release these toxic metals into the environment. Despite the potential for widespread contamination by toxic elements other than mercury, there is far less empirical evidence for such contamination in ASGM communities, and only a limited number of studies are now documenting contamination by metals in a number of sites in Ghana (e.g., contamination of water and food with relatively high levels of arsenic, cadmium, lead). Because such studies have so far been focused in southwest Ghana, the extent of pollution in northern Ghanaian mining areas is not well documented, making spatial and temporal trends difficult to assess.

Water Quality

Certainty level: Moderate (some scientific publications; plausibility, strength of association)

Given evidence from several studies assessing water quality parameters in ASGM areas [14], ASGM activities are affecting water quality, although the majority of studies are from the south-western regions of the country. Temporal data is insufficient to determine the seasonal and short- and long-term impacts of mining on water quality and quantity. While there has been a focus in the literature on heavy metals in water and sediment, less attention has been paid to other water quality parameters at ASGM sites. It is also challenging to separate the impacts of large-scale mining, farming, and industrial activities on water quality from those of ASGM since these activities often occur in the same areas where studies have been conducted. Water withdrawal due to ASGM is a concern, but data on surface and groundwater recovery times, critical base flows for headwater streams, and impacts to aquatic life are not currently known.

Land disturbances

Certainty level: Low-moderate certainty

Deforestation is occurring in Ghana, but the extent to which it is tied to ASGM, or even large-scale gold mining, is largely unknown. ASGM activities often leave behind greatly disturbed landscapes, but mining, industrial, and agricultural activities all can contribute to land degradation in a given area. ASGM may impact farming practices and encourage miners and mining communities to farm on marginal land that may be more prone to desertification or soil erosion [71].

Climate Change

Certainty level: Data limited

Ghana is not a major contributor to GHG emissions globally; however, ASGM activities are tied to deforestation and fossil fuel use, which are contributors to climate change. Currently no existing analyses are able to distinguish ASGM from large-scale gold mining in terms of impacts on forests. While there have been no studies from Ghana on the contribution of either ASGM or large-scale gold to climate change, mining-related land use changes and reliance on fossil fuels for certain mining tasks imply that GHG emissions may be worth documenting.

The effects of climate change on the mining sector may be of greater concern of its contribution to climate change. Changing patterns in rainfall and temperature due to climate change are beginning to be documented in Ghana [72]. Ghana’s economy relies heavily on sectors that are sensitive to changes in climate, such as agriculture, fisheries, tourism, and forest services. ASGM experiences influxes in labour when farming becomes unviable [73,74], and this pattern could continue if rural livelihoods face pressure from climatic changes that exacerbate the ecological issues described previously. Given the lack of robust research documenting the effects of climate change in Ghana, evidence-based predictions on the impact within the mining sector cannot yet be made.

Mining Waste

Certainty level: Data limited

Mine tailings pose potential threats to water quality, ecosystem health, and human health. Appropriate management of this waste often requires trucking to offsite locations, which is not typically possible in the resource-limited settings in which ASGM occurs. As a result, waste generally sits indefinitely in the communities in sedimentation ponds or piles [75,76]. According to one study, miners may directly dump waste into local water bodies [77]. Levels of heavy metals in and around tailings in old and current ASGM sites are elevated at some studied sites [27]. Additional research is required to understand the short and long-term impact of mine waste on water quality, ecosystem health, and human health.

3.1.3. Social Sciences and Economics

Poverty and Livelihood: Microeconomic Effects and Needs

Certainty level: Moderate (high plausibility from peer-reviewed, published evidence)

Available evidence from Ghana strongly suggests that the principal microeconomic reasons that most people take up ASGM involve insecurity and inability to meet basic needs [78]. These are known as "push" factors aimed at trying to meet subsistence needs. There are fewer data and some conflicting information that suggest that the "pull" of a "get rich quick" perspective is important to many miners [63,79], though this likely varies across different regions of Ghana. However, there are currently no national comparisons to evaluate the relative importance of these drivers. The available data also suggest with high plausibility that most individuals and their families entering into ASGM end up in a "poverty trap" in which simple extraction methods, insufficient investment, scant alternatives, and lack of education combine to keep these families in a repeating cycle of poverty and dependent on ASGM for survival.

Macroeconomic Effects, Policies and Programs

Certainty level: Moderate

The full magnitude of macroeconomic impact of ASGM is difficult to quantify because of the extensive unreported and unrecorded illegal mining, though mounting evidence points to the significant macroeconomic contributions of ASGM to Ghana's economic performance metrics. Current records of mining activity are considered incomplete and of uneven quality. There is strong evidence that the macroeconomic drivers underlying much of Ghana's ASGM activity are related to the dearth of gainful opportunities in other sectors, which forces many to complement inadequate employment with illegal and dangerous mining. Uncertainty remains, however, as to whether increased regularization would improve the livelihoods and living conditions of ASGM miners and their dependents. It is also unclear whether the new mining laws will achieve their stated goals (of clarifying land rights, educating miners and their families, reducing conflicts, distributing taxation more equitably among miners, etc.). The uncertainty of macroeconomic policy impacts of ASGM exists against a backdrop of high certainty of human health [21] and environmental [27] risks.

Legalization, Formalization and Enforcement

Certainty level: Moderate

Evidence indicates that developing a fair and open ASGM permit process would have the least economic disruption to ASGM, could be used to train miners, would produce some tax revenue and no job loss, and could demonstrate cooperation and interest by the government in miners' future investments and livelihood planning. There is high certainty that such changes would address many of the impediments to regularization, and possibly reduce mistrust of the government. However, implementing such a program would be complicated and costly, and workers will need to be assisted in understanding and complying with the legalization policies [80], while the government ensures improvement in infrastructure to augment ASGM, such as an enhanced road network, reliable electrical power, and safe potable water.

3.2. Response Options

3.2.1. Response Option Development and Evaluation

Based on the data summarized in section 3.1, workgroups developed a set of evidence-based "response options" or actions to address the social, economic, health and environmental issues associated with ASGM. A manuscript detailing the entire response option development and evaluation process has been published [81], and excerpted here:

In the final section of the near-complete drafts of their discipline-specific IA reports, workgroup members first drafted 0-14 response options per workgroup. The response options included the cause or consequence of ASGM that the response option would address, the rationale for that response option, and potential actors and processes involved. We then used the Delphi Technique, an iterative polling method that aims to gauge expert opinion on complex topics [81], to evaluate these options.

In Phase 1 of the evaluation process, (Figure 1) team leaders condensed the 27 original response options into 17 response options (Appendix 8), which were then inserted into an online poll (SurveyMonkey.com). In Phase 2, workgroup members and external advisers used the poll to rate the options in terms of benefit (broken down into the categories of economic benefit, environmental benefit, and benefit to people) and feasibility (broken down into the categories of economic feasibility, social/cultural feasibility, political feasibility, and implementation feasibility) on a four-point Likert-style rating scale (Figure 1). The values on the scale were *very low*, *low*, *high*, and *very high*. The project manager calculated descriptive statistics of the scores for each category of the poll and shared with the participants on the first day of Meeting #3 in April 2014.

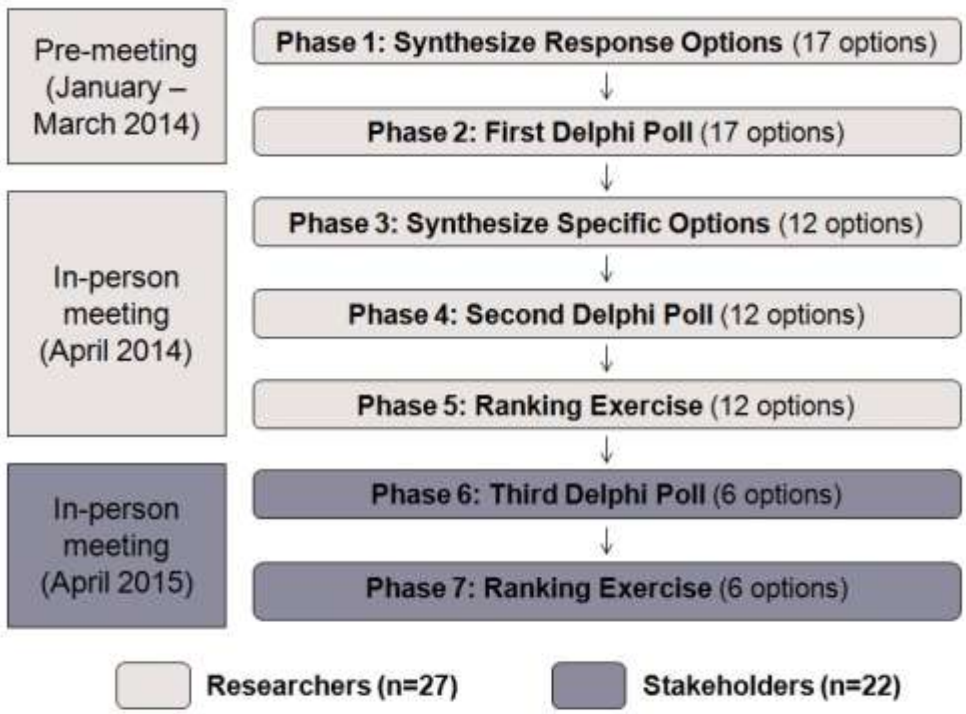

Figure 1. A flowchart of the Delphi exercise. Figure taken from Basu et al. 2015 [81].

The group determined that a greater level of specificity was required for the response options in the first iteration of the poll to be informative enough to rate. For Phase 3, each workgroup developed 3 to 5 *specific* response options (Figure 1). Individual team members first privately developed 6 to 10 specific response options. Each working group then compiled individual members' responses, and generated a list of between 60 and 80 response options per group. From this list, workgroups then distilled and prioritize 3 to 5 specific options to present to the entire team on the second day of the meeting. Working groups were asked to justify their specific response options based on the data in the working group reports, the benefit and feasibility scores from the poll, and their own expertise.

Each working group developed six refined options and presented them to the team on the second day. The entire group discussed each response option after it was presented with the assistance of an experienced facilitator. The team leaders then condensed the 17 total specific response options into 12 specific response options by collapsing similar ideas among the groups (Appendix 8). Once these 12 had been agreed upon, a second Delphi poll (Phase 4) was conducted with the same format as the first and with the new specific response options (Figure 1). The poll was conducted among the working group members present using a Microsoft Excel template that each individual submitted electronically to the project manager. Descriptive statistics of the scores for each category were shared among the entire group on the last day of the meeting (Day 3).

To get a ranking of the 12 specific response options, on Day 3, each participant was given three different colored sticky notes and the options were written out on whiteboards (Phase 5, Figure 1). The team was asked to place their stickers under what they considered the first, second and third most important response options. These results were subsequently transcribed and represented graphically.

A year later, a meeting was convened of relevant stakeholders representing local and national government, academia, NGOs, miners' associations, and other organizations (Appendix 9). Study findings were presented to the stakeholders. Prior to the meeting, the six top response options (A, F, I, J, K, L) from the second round of the Delphi were determined via their consistently high scores on several metrics. These top six options were presented to the group, and in Phase 6 (Figure 1), the stakeholders rated the options using a paper version of the same Delphi poll questions described for the first two Delphi polls. Participants also indicated a ranking of the top three most important options on this paper poll (Phase 7, Figure 1). These results were also transcribed and represented graphically. The results of these polls provided an evaluation, based on expert opinion, of the likely outcomes of these response options.

Results of the Second Delphi Poll

Of the 12 scenarios in the second Delphi poll, the three options with the greatest benefit scores were Option L (Universities, EPA, the Minerals Commission explore and implement high yield mercury free alternatives), Option K (Royalty from proceeds of mining needs to be placed into a central account and directed towards improving health and environment of ASGM communities) and Option E (Government should provide utilities in partnership with enterprises to ASGM communities and other affected communities). The three scenarios with the greatest feasibility were Option A (Establish a national framework for policy and planning implementation that considers stakeholder input), Option H (Minerals Commission, EPA, miners, universities. study on pilot enforcement and implementation to assess effectiveness of laws) and Option J (Public/private support education with ASGM on ecological and human health risks, Hg and metals, Hg reduction strategies and business practices) (Figure 2). The three scenarios with the greatest score overall were Option J, Option L and Option K (data not shown).

For the second poll, both in terms of benefit and feasibility, there was little variation between the options (σ=0.23 and σ=0.14 respectively), with Benefit scores ranging between 2.96 and 3.52 and Feasibility scores ranging between 2.52 and 3.1. In terms of benefit respondents tended to score options higher in terms of Benefit to People (μ=3.5) and lowest in terms of Environmental Benefit (μ-3.05). For Feasibility, scores were highest in terms of Social/Cultural Feasibility (μ=3.04) and lowest for Implementation Feasibility (μ=2.73). In all cases, respondents perceived the benefit of the options to be greater than their feasibility. In particular, options tended to score lower in political and implementation feasibility, suggesting the existence of institutional barriers preventing scenarios from being realized. In the respondents comments, this was expressed, with respondents citing lack of trust between miners and the government and lack of political will to address the issues surrounding ASGM as key barriers to reform. Another important trend that emerged was the high level of similarity among the benefit scores (μ=3.08, μ=3.05, μ =3.5). In some cases, a large discrepancy between the different benefits occurred. This suggests that in some cases respondents saw a trade-off between economic, environmental and social benefits.

Results of the Stakeholder Poll

At the meeting conducted one year after the initial Delphi meeting, stakeholders rated the six top response scenarios (A, F, I, J, K, L). Options J and L are rated the highest across all the groups. Figures 3a and 3b show the relative benefit and feasibility of the six options. Across all the groups, Option L had the highest benefit while Option A had the highest feasibility. In general, the benefit of the options was perceived to outweigh their feasibility.

Results of the Sticky Note Exercises

The results of the sticky note exercise showed a much greater degree of variability than the Delphi polls. First choices were highly concentrated among Options J and L (Figure 4).

Figure 4c shows the weighted scores for each of the groups. Once again Options J and L are the most desirable options.

While there tended to be high levels of agreement both between and within options the same was not true of the Sticky Note Exercise. As discussed above, people's choices tended to be a lot more concentrated, with a few high scoring options emerging. Interestingly enough, despite the Sticky Note Exercise not being part of the standard Delphi technique, it was more effective than the questionnaires in building a consensus, with responses clustering around two top options. Whereas in the questionnaires there was no limit on respondents' ability to score options, allowing them to rank them more or less equally, in the Sticky Note Exercise they were more constrained, forcing them to prioritize.

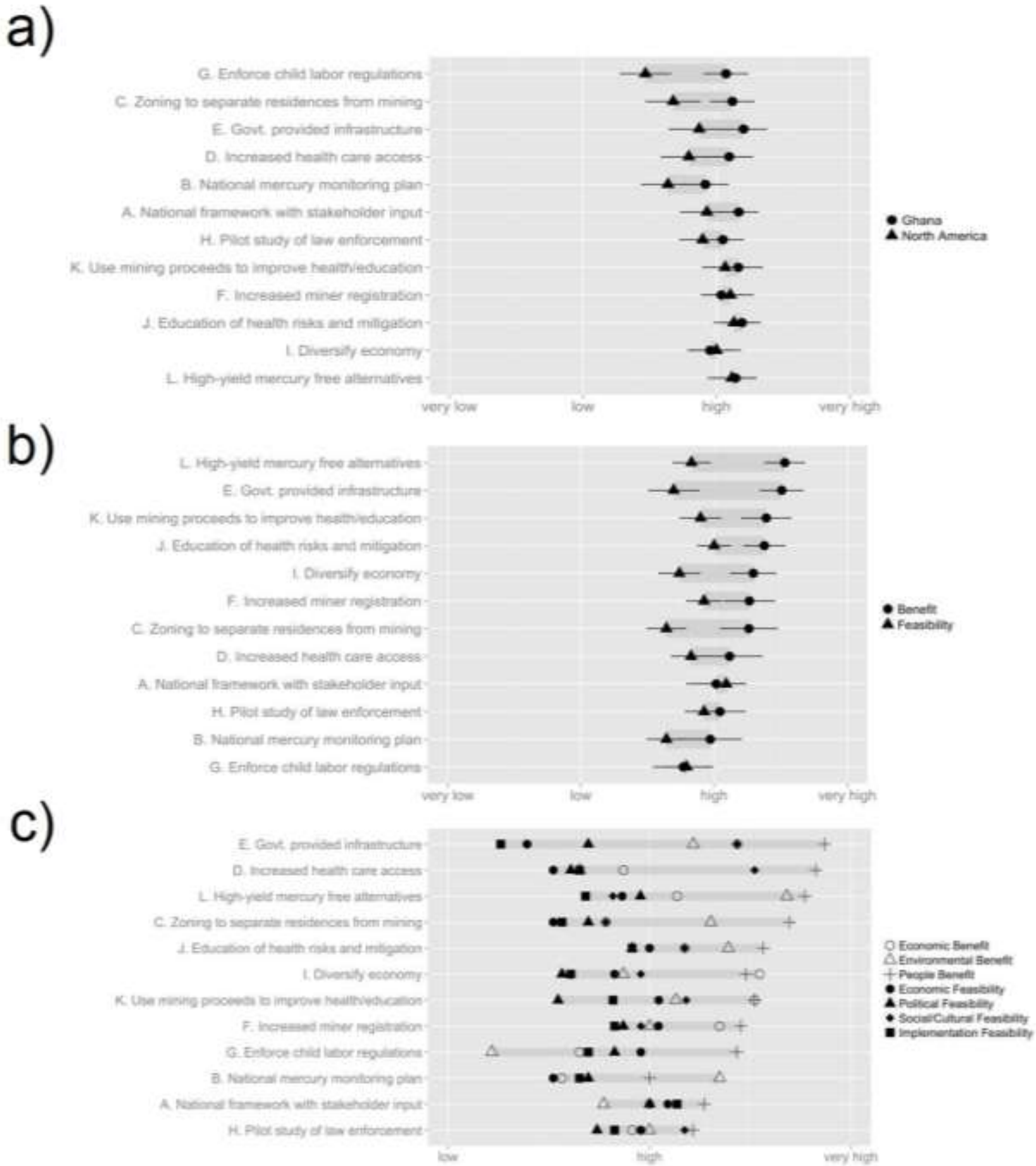

Figure 2. Delphi poll scores from the second Delphi poll, conducted among academics (n=27) in April 2014. a) Overall score for each option, grouped by region, sorted by difference; b) Overall score for each option, grouped by benefit and feasibility, sorted by decreasing benefit; c) Overall score for each option, grouped by topic, sorted by maximum benefit/feasibility. Figure taken from Basu et al. 2015 [81].

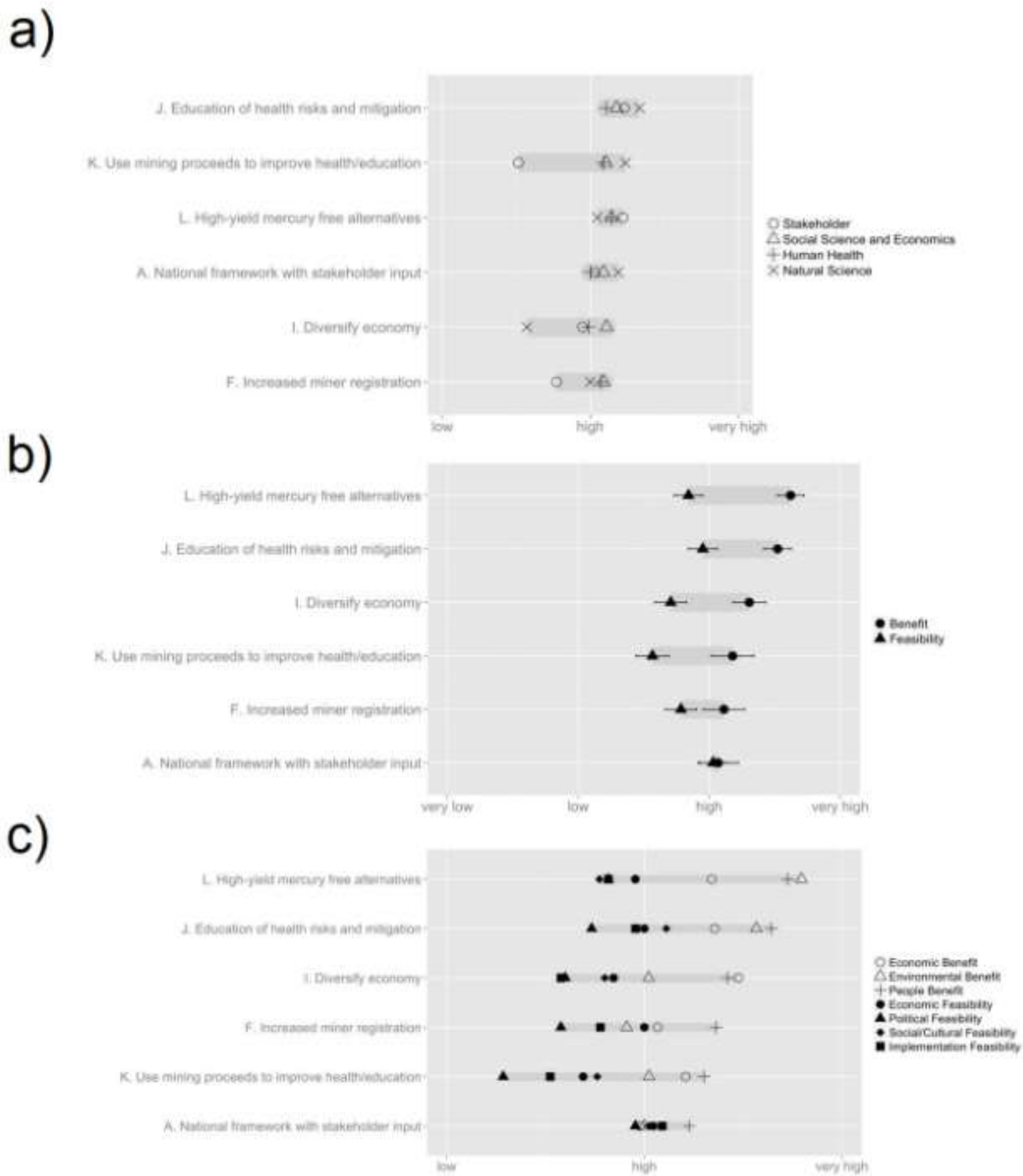

Figure 3. Delphi poll scores from the third Delphi poll, conducted among stakeholders (n=22) in April 2015. a) Overall score by workgroup; b) Overall benefit and feasibility scores for all groups; c) Benefit and feasibility score for each option grouped by topic. Figure taken from Basu et al. 2015 [81].

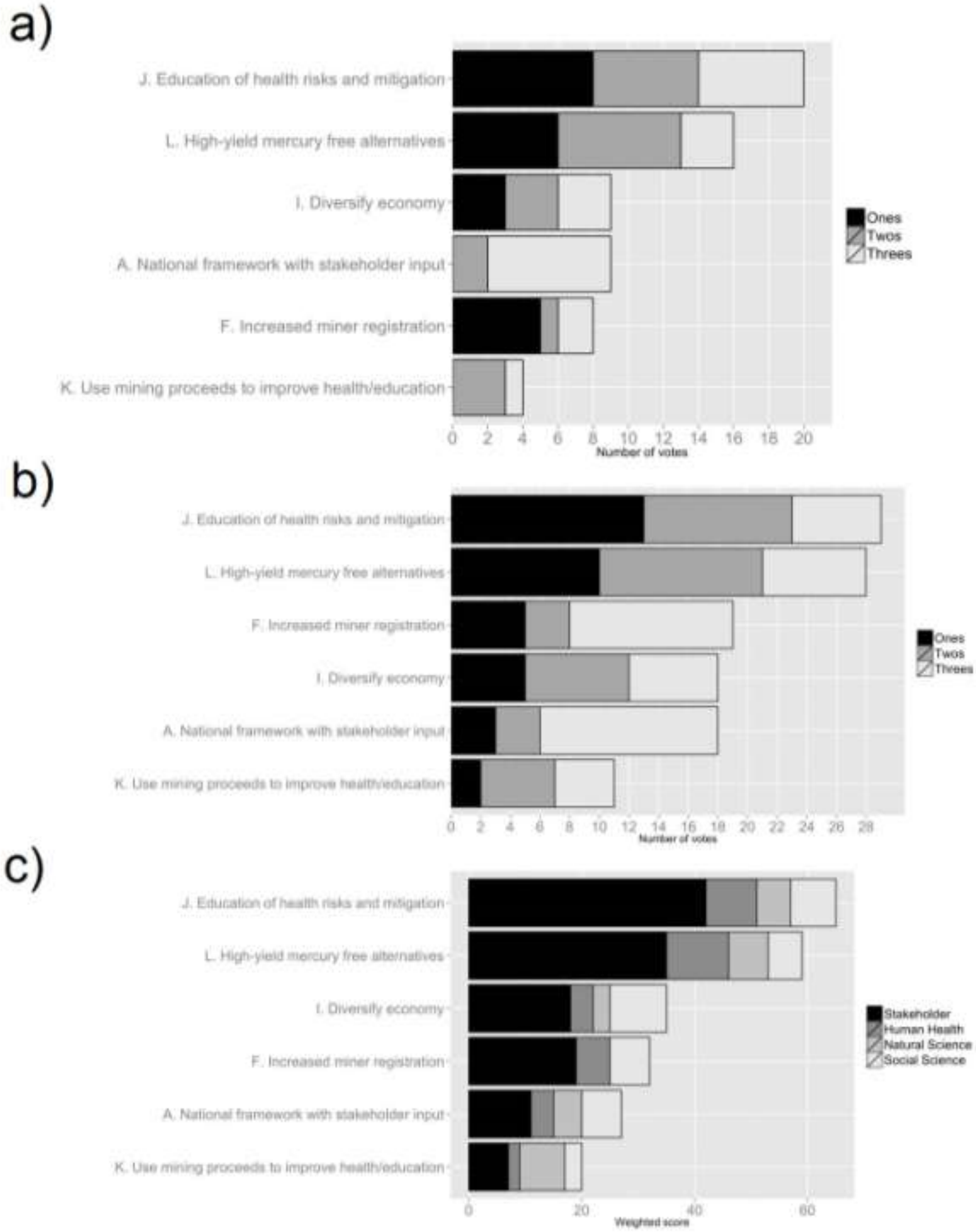

Figure 4. Results from sticky note exercise used to prioritize response options, conducted among academics (n=27) in April 2014 and among stakeholders (n=22) in April 2015. a) Number of votes for each option; b) Combined sticky note scores for all groups (academics and

stakeholders); c) Weighted scores for each option, grouped by workgroup. Figure taken from Basu et al. 2015 [81].

3.2.2. Limitations

Experience with the Delphi technique suggests it has a number of important benefits which serve to justify our use of it in this project. However, there are a number of important criticisms and limitations to consider both when analyzing our results and when considering future Delphi use. First and foremost of these is the use of the term “experts," which can be exclusionary and privileges some forms of knowledge over others. Our first panel was comprised of Ghanaian and North American academics, and our second panel included members of several stakeholder organizations. While respondents' decisions may be informed by conversations they have had with small-scale miners in the field, in the future more effort should be made to incorporate their direct involvement in the Delphi process.

Another important limitation to consider is the overly quantitative nature of Delphi. While the point system used is effective in surveying a large group of individuals, organizing information and observing statistical trends, it does have a tendency to simplify responses and ignore nuance. While respondents were asked to rate options based on different feasibility and benefit criteria, little information is available to understand the respondents' rationales. While a comments section was provided, only some respondents choose to elaborate on their decisions. While a lot of discussion did occur informally between polls in the workgroup and team sessions, these sessions were not recorded, leaving little than can be incorporated into the final report. Past Delphi polls have been conducted in which respondents are asked to include qualitative rationales to defend their quantitative responses, which are then shared with the rest of the group [82], an option which it might be advisable to pursue in the future. In addition, by formulating priorities by looking at those options with the highest mean scores and lowest standard deviations, outliers are often missed and differences between respondents are erased. As Tapio writes, often cases of discord rather than consensus prove the most enlightening, [83] an idea not emphasized in this study.

A final criticism to consider is the role social pressures may have played in shaping respondents' decisions. In theory the anonymous polling of the Delphi technique is supposed to limit these pressures [84]; however, in many cases they continue with participants over-valuing their own opinion, undervaluing those of others, and conforming to those views perceived as dominant [82]. Thus it is important to consider what role these pressures played in shaping group opinion, especially during face-to-face interactions such as the between poll sessions or the Sticky Note Exercise.

4. Additional Considerations and Limitations

Policy should be grounded in objective peer-reviewed science rather than anecdotes and assumptions, and speculation and opinions are not adequate grounds for new policy changes. Unfortunately, gaps in data availability, not only in Ghana but elsewhere in the world where ASGM occurs, prevent a full assessment of the status, trends, causes and consequences of all ASGM-related concerns. This is particularly important now given the consideration ASGM has been given in the UN Minamata Convention. The limitations of our IA are described below.

First, within Ghana is a vast variety of communities, cultures, landscapes, and ecosystems home to small scale gold mining. For example, one general trend is that the South of Ghana is more tropical and economically developed than the North, and the two regions are distinct culturally. Though some risk factors for health (e.g., mercury use, poor sanitation) and for ecological disturbance (e.g., mercury contamination, land use degradation) are expected to be ubiquitous across Ghana, others may be specific to certain locales. For example, content of lead or arsenic in the mined ore may vary with geological makeup of an area, or health outcomes may be influenced by local behaviors and availability of health care services. Data are insufficient to meaningfully distinguish among Ghana's many mining sites and their variations.

The dearth of comparative data between legal and illegal ASGM communities makes it difficult to distinguish impacts that may be specific to one of these two types of mines. The two groups of miners use similar methods for obtaining mineral-laden ore and for extracting the gold and other precious metals, but depending on their legal status, miners may have differing access to governmental or other resources. The number of ASGM miners who operate illegally is unknown and there is uncertainty with the estimates provided, which range from 60% to 80% [85,86].

In general, the lack of coordination among research institutions, academia, and policy-makers, the shortage of funding for the study of ASGM issues; and the insufficient political will to implement policies all create obstacles for data collection on ASGM in Ghana. Furthermore, the legal and institutional frameworks concerning mining in Ghana all pose barriers to providing and exchanging information and implementing changes.

Specific data gaps set limits on what could be achieved through the IA. Regarding human health concerns, the lack of detailed exposure assessment information for metals and other contaminants for any ASGM site limits the ability to assess risk in a meaningful or quantitative manner, or establish causal linkages between exposure and disease. Though some biomarker studies and mostly survey-based health assessments have been performed, a rigorous assessment that links source, fate, exposure, and health outcomes has yet to be achieved.

Another limitation to understanding the human health impacts of ASGM is that the Ghanaian health care system may overlook ASG miners and communities, which makes health surveillance in these communities a challenge. Because of financial and geographical barriers to accessing health facilities, lack of familiarity with health care systems, or in some cases, illegal status, we assume that ASGM participants are less likely to participate in the government health system. As a result, they are likely often missed in disease surveillance [87–92].

In addition, observations of ASGM-related health impacts may be biased toward direct and visible trauma and/or short-term acute effects that are easier to document. Longer-term adverse health outcomes such subtle loss of neurological function due to mercury poisoning or psychological stress from work demands may be missed entirely by most disease surveillance efforts [88,93].

An additional data gap is that concerning the status of non-miners in mining communities, and the status of women and children miners. In most ASGM settings, women and children are actively engaged in ASGM activities, and there tends to be little separation between residential and mining activities. Vulnerable populations and community residents are thus exposed to hazards that arise from ASGM. Most studies focus on miners themselves, and thus these exposures are especially difficult to document without active monitoring that targets these groups such as women and children [92].

Finally, identifying the 'cause' of some human disease events is challenging if the more 'distal' factors are considered, as indirect pathways through social or environmental vulnerabilities may be occurring. For example, an indirect human health impact of ASGM on nutrition could be that crop production and food availability is diminished, which would have a large effect on human health. Another example might be that the risk of malaria might be greater in ASGM communities if mosquito breeding sites are created by mining activities, or that sexually transmitted infections may become more common if ASGM disrupts the social fabric of communities. Human health impacts of ASGM with more complex causal pathways are therefore difficult to fully assess.

In terms of assessment of ecological impacts, it is often a challenge to distinguish impacts of ASGM from those of other economic activities on the natural environment in Ghana, as many studies are based in areas with varied and overlapping activities (i.e., large, small-scale, and illegal mining activities occurring simultaneously). Furthermore, clusters of ASGM sites make it difficult to isolate impacts associated with any single site.

5. IA Evaluation

The IA process and outcomes were evaluated through several means. First, annual surveys were undertaken at in-person team meetings in Accra. Annual surveys of the project were carried out in 2012, 2013, 2014, and 2015. In brief, the surveys included quantitative questions addressing the current meeting and the IA process and qualitative, open-ended questions allowing participants to reflect on the meeting and the IA process. The data from these surveys are presented in Appendix 6. Second, project outputs - publications, presentations, trainees and researchers engaged, etc. - were compared with the goals established at the outset of the IA. Taken together, these activities helped evaluate the IA in terms of technical adequacy, value, legitimacy, and effectiveness.

5.1. Technical Adequacy

The technical adequacy of the IA has been demonstrated by the number of publications our team has published through peer-review process, the number of presentations given at conferences around the world, and by the judgment of the international experts involved in the project. Since the first stages of the project, in 2009, to date, 21 publications have been published through the peer-review process, one has been published through non-peer-reviewed avenues, and several more have been submitted or are in progress. Fifteen of the published and submitted papers are found together in a special journal edition in the International Journal of Environmental Research and Public Health (IJERPH) (http://www.mdpi.com/journal/ijerph/special_issues/asgm), which was co-edited by IA PI (Basu) along with two of our international, arms-length experts (Keane, Black-Moher).

Since 2009, at least 10 presentations on research by our team related to the IA have been given at international and local conferences (Appendix 11). We have finalized a series of eight fact sheets (Appendix 1) as well as data resources that, for example, outline the relevant mining laws in Ghana, provide a table of mercury content in nearly 10,000 specimens (i.e., fish, tailings, sediment, plants, soil, water, hair, urine) from across the country, and summarize workgroup findings [27].

5.2. Value

The IA is timely and of value to within Ghana and internationally for several reasons. First, the IA is warranted in light the recent increase in gold prices, global economic crises, expansion of resource development across Africa, growth of the ASGM sector globally, and a dearth of data on the causes and consequences of ASGM.

Second, in 2013, the member nations of the United Nations Environment Program (UNEP) agreed to the Minamata Convention on Mercury. Within the Convention, both a stand-alone article (Article 7) and a dedicated Annex (Annex C) address the ASGM sector. Per these sections of the Convention, countries such as Ghana with sizable ASGM sectors must develop a public health strategy for ASGM communities, with particular attention to protecting vulnerable populations such as women of childbearing age and children. The Convention also encourages signatory nations to take part in education, outreach and capacity-building initiatives specific to ASGM (7.4B), and in general strengthen public health measures to address mercury pollution (Article 16), especially protection of vulnerable groups (women and children; 16.1A) with specific mention of strengthening of institutional and health professional capacities (16.1D). Furthermore, in response to the estimation that about 80% of ASGM miners are not registered under the terms of the Minerals and Mining Act of 2006 (Act 703), and thus conducting mining illegally (personal communication with Ghana Minerals Commission, 6 August 2014), the President of Ghana initiated an Inter-Ministerial Task Force on Small-Scale Mining in 2013 to help bring the sector into compliance with the registration law. In addition, the National Development Planning Commission (NDPC), which reports to President, has recently identified ASGM as a sector requiring immediate policy action because of its major economic, social, and national security implications. Our efforts to share results of this Integrated Assessment with the aforementioned programs and other pertinent stakeholders should help provide strong, scientific evidence upon which to base these initiatives and policy changes.

The value of the IA to the participants was evaluated throughout the course of the project via survey. On a scale where 5 = Excellent, 4 = Very Good, 3 = Good, 2 = Fair, 1= Poor, meeting participants were asked to rate the value of the meeting and IA process in addressing the problem and research questions. At Meeting #1, participants gave this criterion a mean score of 4.3. At Meeting #2 and Meeting #3, 100% and 85%, respectively, of participants scored this criterion as either "Excellent" or "Very Good" (Appendix 6). Qualitative comments collected about the IA process and meetings emphasized the opportunity the IA provided to have open and frank discussions, network with other researchers, strategize, and exchange knowledge across disciplines. As one participant stated, the IA meeting was "Great for sharing ideas, for identifying individuals and groups to engage in the future, and to vet ideas collectively." Another indicated that "Getting to meet and work with group members, exchanging information, [and] hearing about the other panelists' research," was a positive aspect of the IA meeting.

5.3. Legitimacy

Throughout the IA, a wide range of stakeholders has been engaged from across disciplines and sectors (Appendix 3). Throughout the process we left spots in each workgroup to invite other experts not currently engaged. In-person meetings were designed so as to enable open dialogue and encourage diverse perspectives. Engagement was tracked via responsiveness to emails and online polls, and participation in both in-person and virtual meetings.

Fairness and legitimacy in the process were also evaluated during the annual surveys. When asked to rate the IA's inclusion of appropriate stakeholders using the aforementioned scale, at Meeting #1, participants gave this criterion a mean score of 3.7. At Meeting #2, approximately 50% of participants indicated that inclusion was "Excellent" or "Very Good" with about 45% indicating "Good." A similar trend was seen in the survey for Meeting #3 (Appendix 6). It should be noted, however, that a theme in the qualitative comments for both Meeting #2 and Meeting #3 was the need to include more diverse stakeholders, such as policy-makers, mining engineers, ASGM miners, and local governments, as well as the need to allow more time for discussion and networking at IA meetings. For example, regarding engagement of diverse stakeholders, one participant said, ""The interdisciplinary nature of the groupings and the membership enhances the integration of perspectives and therefore enhances the likelihood of solutions addressing the real problems," while another wrote, "Inclusion of policy makers during the process could improve ownership and hence facilitate policy dialogue and implementation."

5.4. Effectiveness

The effectiveness of the IA will be ultimately be determined by its influence on policy and interventions related to ASGM, and on the success of these policies and interventions in attaining their goals. While it is too soon to ascertain this, the international policy landscape concerning ASGM is undergoing rapid and escalating changes worldwide, and our IA is expected to inform policies in Ghana and potentially elsewhere.

Aside from the long-term policy goals of the IA, we assessed its effectiveness in achieving other sub-goals, such as building networks and bringing together diverse stakeholders. Scores on our annual surveys regarding the effectiveness of our meetings in achieving the goals of the IA were consistently high, with most mean scores on items pertaining to meetings above 4.0 (Appendix 6). Scores for " Exchange of knowledge," "Formation of partnerships," and "Integration among diverse stakeholders/experts" were also consistently high, and in the qualitative comments, a common theme was the usefulness of the IA in bringing together diverse disciplines and providing a forum for interaction and discussion. As mentioned above, however, some qualitative comments indicated a need to include more diverse stakeholders in the process. One participant wrote, ""This meeting provided a great forum for all members to come together and voice their ideas and opinions." On the topic of including more diverse stakeholders, another said, "The clear thing that is missing is the voice of the miners themselves. It is important to find key representatives/spokesperson who can speak on behalf of one interest of the miners/operators."

The IA's success in training of students and researchers (Appendix 2), bringing together local and international experts (Appendix 3), generation of presentations and publications (Appendices 10 and 11), and growth of allied projects and collaborations (e.g. GEOHealth and PARTNER II) are all indications of its effectiveness in rallying multidisciplinary expertise around a "wicked" issue.

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Appendix 1a.

Ghana Mining History

4,000 YA — First human settlement of Ghana

600-700 CE — Ghana emerges as main gold supplier to the Arab world

1324 — Malian Emperor Mansa Musa makes his famous pilgrimage to Mecca; collapses the Mediterranean market with Ghanaian gold

1400 — Market for Ghanaian gold shifts west as European colonialism begins

1900 — Ashanti, the last independent Ghanian kingdom is conquered by the British and incorporated into the Gold Coast Kingdom

1900-1930 — Concentration of mining concessions in European hands; first galamsey emerge

1957 — Ghana regains independence; mines nationalized to fuel development

1983 — Government implements neo-liberal reforms including the privatization of the mining-sector, opening up the country to foreign investment

2006 — New mining code is formulated seeking to further foreign investment while addressing the needs of smale-scale miners

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Gavin Hilson and Clive Potter, "Structural Adjustment and Subsistence Industry: Artisanal Gold Mining in Ghana"

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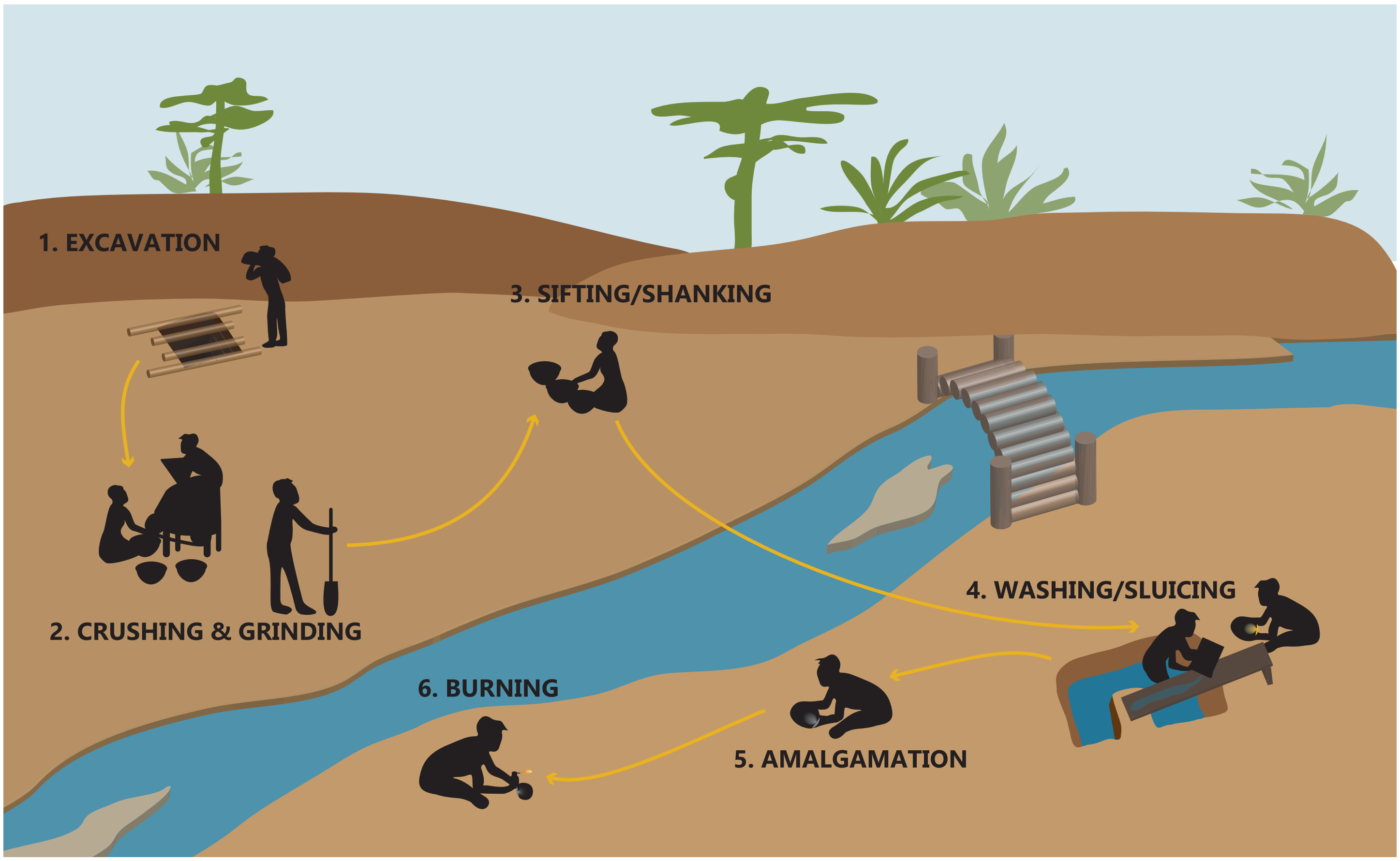
Appendix 1b.

The ASGM Process

The level of mechanisation in the ASGM process varies slightly from place to place. At some ASGM sites, miners may use pickaxes and shovels for excavation and mortars and pestles for grinding the ore, whereas others might use bulldozers or dynamite, and have generators to power grinding machines. However, the six basic steps, outlined below, occur in most ASGM sites.



1. EXCAVATION - Gold ore is mined from surface soils or underground mine shafts. Panning in rivers or harvesting the tailings of large-scale mines are also common practices.
2. CRUSHING & GRINDING - Large pieces of ore are crushed and ground by hand or using grinding machines to release gold particles.
3. SIFTING/SHANKING - Ore is sifted to separate large particles from finer ones. Large particles may be reground.
4. WASHING/SLUICING - Gold is concentrated through a washing process. This sometimes involves washing the pulverized ore down a carpeted ramp. The carpet traps dense gold particles as the rest of the ore runs down the ramp.
5. AMALGAMATION - Mercury is added to the concentrated gold particles to form a gold-mercury amalgam.
6. BURNING - The amalgam is heated with a blowtorch or small fire, evaporating the mercury and leaving a porous "sponge gold" product that is sold and further refined for sale on the world market.

Figures and text adapted from:
UNEP (2013). Mercury - a time to act. Available at: http://www.unep.org/PDF/PressReleases/Mercury_TimeToAct_hires.pdf
UNEP (2012). A Practical Guide - Reducing mercury use in artisinal and small-scale gold mining. Available at: http://www.unep.org/chemicalsandwaste/Portals/9/Mercury/Documents/ASGM/Techdoc/UNEP%20Tech%20Doc%20APRIL%202012_120608b_

GM IA Ghana-Michigan Gold Mining Integrated Assessment

Glossary of Terms

Many terms related to small-scale gold mining are difficult to define universally, as small-scale mining occurs in many social, political, and economic contexts, and for many geological minerals, all over the world. In our Integrated Assessment (IA), we use these terms in a way that is appropriate for the Ghanaian context. Below we define these terms as they will be used throughout the IA.

Artisanal gold mining - Gold extraction, legal or illegal, conducted by individuals or groups with limited capital investment using manual labor, basic tools and/or simple machinery. Often interchangeable with "small-scale gold mining", but sometimes used for illegal mining,[1] or purely manual, very small-scale mining.[2,3]

Artisanal/small-scale gold mining (ASGM) - Used to encompass both less-mechanized, more-rudimentary artisanal gold-mining as well as more-mechanized small-scale gold mining.

Galamsey - A label local to Ghana used to describe illegal, unregistered artisanal miners. The literal translation is "gather them and sell".[4] May imply defiance against the law.[2]

Illegal small-scale gold mining - Small-scale gold extraction conducted by operations not registered with the Ghanaian government according to the criteria specified in the Small-Scale Gold Mining Law of 1989.

Informal gold mining - Synonymous with artisanal/small-scale gold mining, though sometimes associated with illegal small-scale gold mining.[5,6] The informal sector is defined as self-employment and unpaid family activities, such as mining.[7]

Large-scale gold mining - Gold extraction operations that are large both in physical size and capacity, using heavy equipment and advanced mining technology, usually foreign-owned. Large-scale mining can include operations that are large both in physical size and capacity, and utilize heavy equipment and advanced mining technology.[8]

Legal small-scale gold mining - Small-scale gold extraction conducted by operations registered with the Ghanaian government according to the criteria specified in the Small-Scale Gold Mining Law of 1989.

Small-scale miner - Any individual directly engaged in any of the six main stages of the small-scale mining processes: excavation, crushing/grinding, sifting/shanking, washing/sluicing, amalgamation, or burning.

Small-scale gold mining - The Ghana Small-Scale Mining Law of 1989, "small-scale gold mining operation" is "the mining of gold by any method not involving substantial expenditure by an individual or group of persons not exceeding nine in number or by a cooperative society made up of ten or more persons." Internationally, this is often interchangeable with "artisanal gold mining," but sometimes refers to more mechanised mining techniques or more permanent mining enterprises.[2]

Surface mining - Any elluvial, colluvial, or alluvial gold extraction, small-scale or large-scale, legal or illegal, that excavates gold from surface deposits and that does not involve excavation of hard sub-surface ore. The Ghana Minerals Commission describes surface mining as "colluvial/eluvial mining using Chinese-made processing equipment, and alluvial mining along the banks of major rivers."[9]

Underground mining - Any gold extraction, small-scale or large-scale, legal or illegal, that involves excavation of hard sub-surface ore. The Ghana Minerals Commission describes surface mining as hard rock mining that employs largely rudimentary methods of underground mining.[9]

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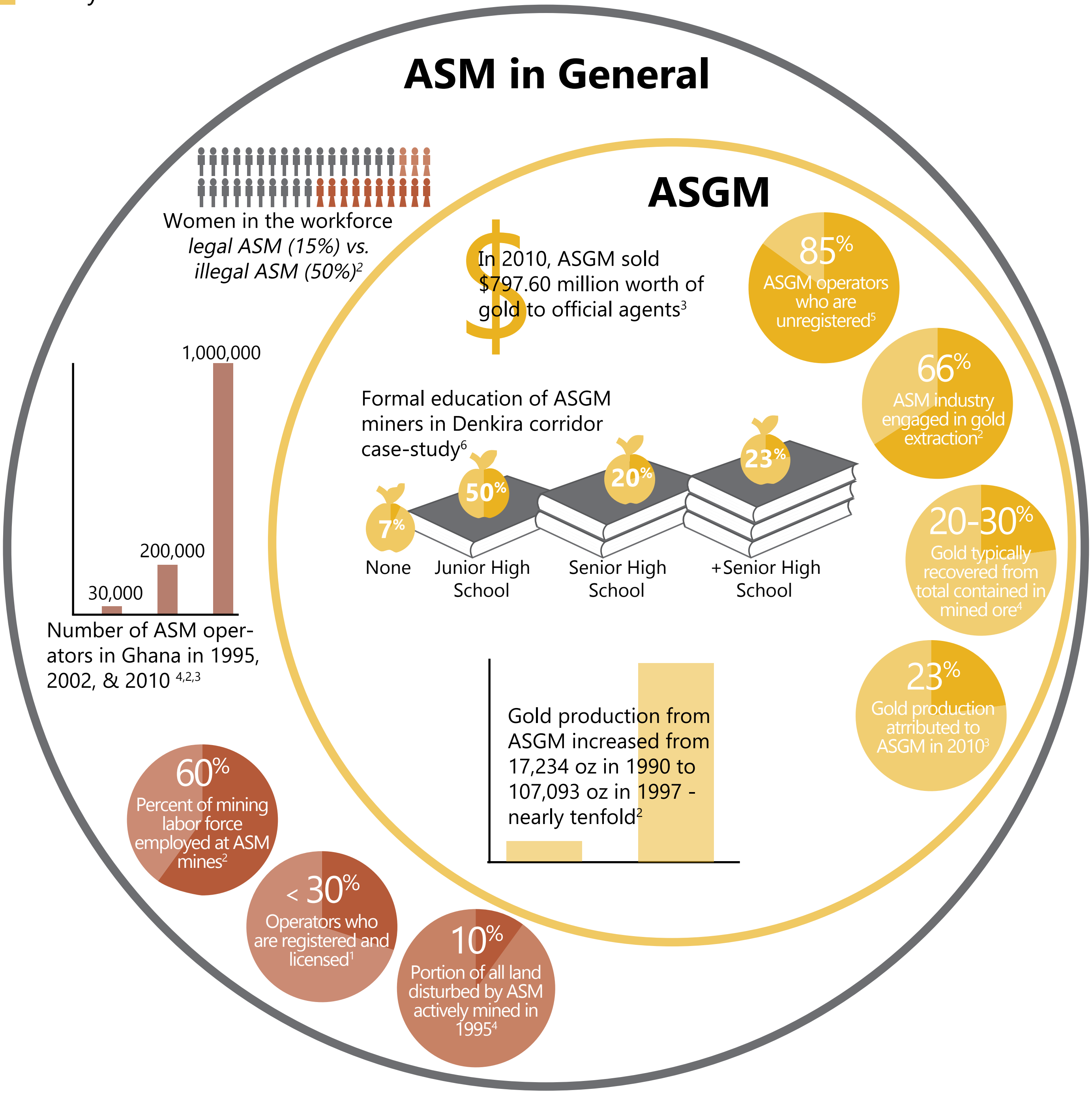
Appendix 1d.

ASGM in Ghana

Because much ASGM in Ghana is unregulated, it is challenging to collect accurate data on the industry. What data exist may be only estimates, and may only apply to artisanal and small-scale mining (ASM) broadly, not artisanal and small-scale gold mining (ASGM) specifically. Below are some estimated statistics that are available on ASM and ASGM in Ghana.



[1]Aubynn, Anthony. 2009. "Sustainable Solution or a Marriage of Inconvenience? The Coexistence of Large-Scale Mining and Artisanal and Small-Scale Mining on the Abosso Goldfields Concession in Western Ghana." Resources Policy 34 (1-2): 64–70.

[2]Hilson, Gavin. 2002. "A Contextual Review of the Ghanaian Small-Scale Mining Industry." Mining, Minerals and Sustainable Development 76.

[3]Tetteh, Kofi. 2010. "An Overview of Ghana's Artisanal and Small-Scale Mining (ASM) Sector". Minerals Commission of Ghana.

[4]World Bank. 1995. Staff Appraisal Report, Republic of Ghana, Mining Sector Development and Environmental Project. World Bank Report No. 13881-GH, Industry and Energy Operations, West Central Africa Department, Africa Region.

[5]Hilson, Gavin & Potter, Clive. 2003. "Why is Illegal Gold Mining Activity so Ubiquitous in Rural Ghana? African Development Review 15 (2-3): 237-270.

[6]Kessey, Kwaku Dwumor & Arko, Benedict. 2013. "Small Scale Gold Mining and Environmental Degradation , in Ghana : Issues of Mining Policy Implementation and Challenges." Journal of Studies in Social Sciences 5 (1): 12-30.

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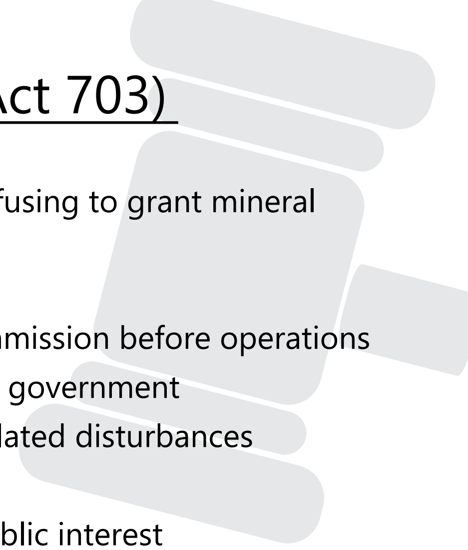
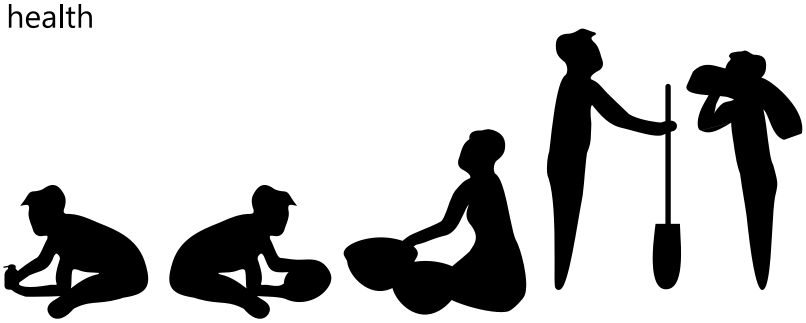
Minerals and Mining Act

Recently amended in 2006, Ghana claims to have one of the most business-friendly mining codes in the developing world, with low tax and royalty rates as well as a number of provisions to enhance investor security.[1] Despite this the new law, much like the 1986 Act it replaced, has been criticized for favouring investment from foreign companies, rather than an approach that addresses the economic needs of Ghanaians.[2,3] Of particular concern are Section 82 to 99 of the Act, which address small-scale and artisanal mining (ASM) activities. While the 2006 Mining Law does include key provisions intended to regulate ASM, lack of implementation undermines its effectiveness. [4,5] Getting a concession is costly and inefficient, providing little in the way of an incentive. The large number of illegal gold dealers and mercury sellers allow miners to bypass government restrictions,[6] while under funding means training centres meant to educate miners about safer practices lack capacity.[7] An estimated 85% of ASM remains informal or semi-formal, often with important environmental and health effects.[5]



Details - Minerals and Mining Act, 2006 (Act 703)

- Article 1 - Minerals are the property of the state
- Article 5 - Minister of Mines must give a written explanation for refusing to grant mineral rights
- Article 6 - Must have a concession to exploit a resource
- Article 18 - Must have the approval of the EPA and the Forest Commission before operations
- Article 48 - Companies can enter 15 year stability agreements with government
- Article 73 - Landowners can claim compensation due to mining-related disturbances
- Article 82 - *Requirement of a license for small-scale mining
- Article 87 - *The Minister can revoke a license if it is seen in the public interest
- Article 90 - *District officers can register miners,monitor operations, provide training, submit reports to the Minerals Commission and facilitate the formation of Small Scale Miners' Associations
- Article 96 - *Miners can only buy mercury from government authorized dealers
- Article 99 - *Buying and selling minerals without a license is a criminal offense
- Article 110 - Minister can further regulate mining activities for public and environmental health



* Pertains to ASM

[1]Martin Kwaku Ayisi, "Ghana's New Mining Law: Enhancing the Security of Mineral Tenure," (2009) Journal of Energy & Natural Resources Law 27:1.
[2]Benjamin A. Teschner, "Smal-scale mining in Ghana: The government and the galamsey," (2012). Resources Policy 37.
[3]Gavin M. Hilson, "Structural Adjustment in Ghana: Assessing the Impacts of Mining-Sector Reform," (2004) Africa Today 51:2.
[4]Benjamin A. Teschner, "Smal-scale mining in Ghana: The government and the galamsey," (2012). Resources Policy 37.
[5]Sadia Mohammed Banchirigah, "Challenges with eradicating illegal mining in Ghana: A perspective from the grassroots" (2008) Resources Policy 33.
[6]Benjamin A. Teschner, "Small-scale mining in Ghana: The government and the galamsey," (2012). Resources Policy 37.
[7]Petra Tschakert and Kamini Singh, "Contaminated Identities: Mercury and marginalization in Ghana's artisanal mining sector" (2007) Geoforum 38.
Images adapted from: UNEP (2013). Mercury - a time to act. Available at: http://www.unep.org/PDF/PressReleases/Mercury_TimeToAct_hires.pdf

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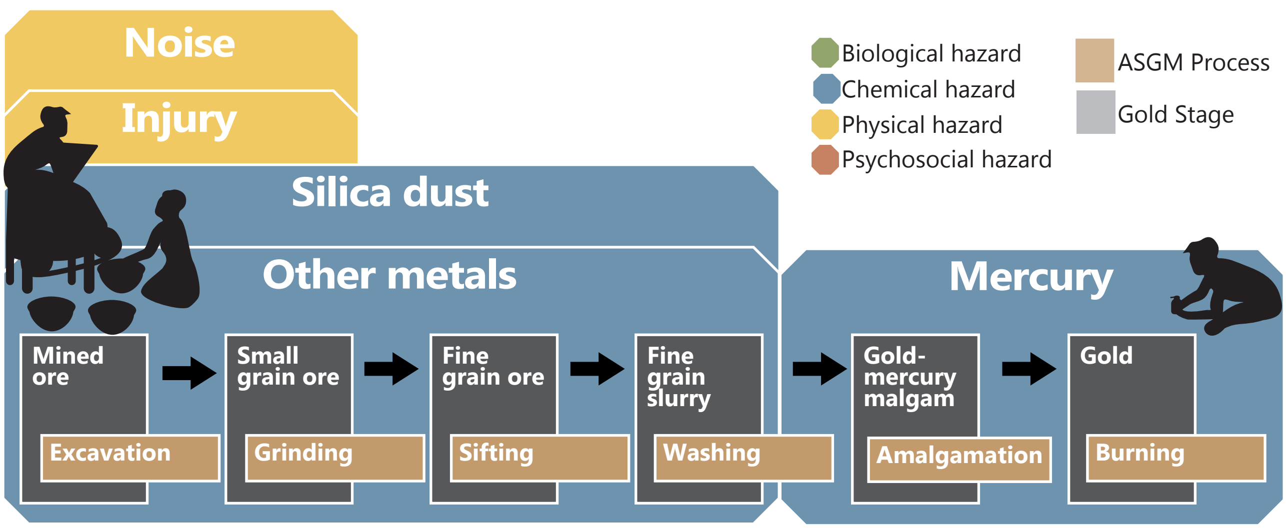
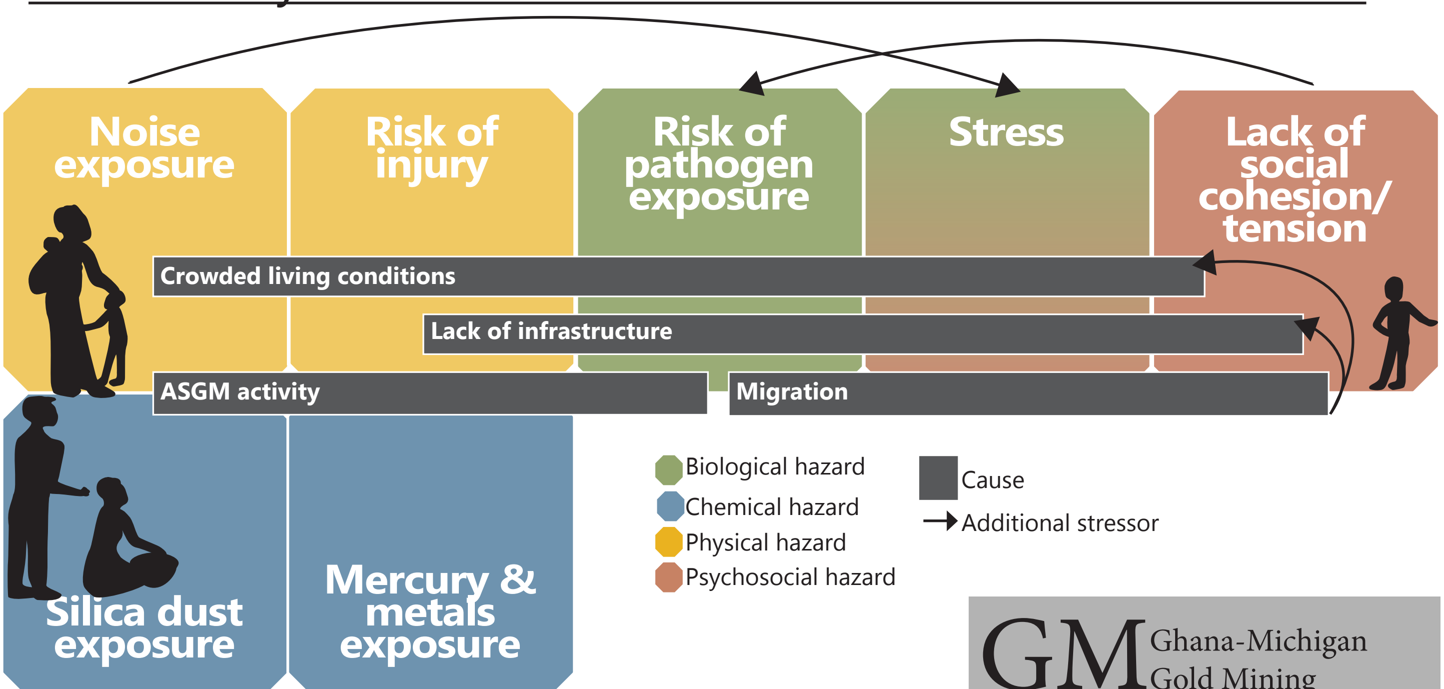
Common Stressors

The small-scale gold mining process and the environmental conditions surrounding small-scale mines create many hazards for both individuals directly involved in the mining process as well as individuals simply living in the surrounding community. While there is limited research to quantify the incidence of injury and disease caused by conditions in mining communities, much observational research suggests that these hazards exist and may cause adverse health outcomes for miners, their families, and the broader community.

Occupational Health Hazards



Community Health Hazards



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Silhouettes adapted from: UNEP (2013). Mercury - Time to act.

Appendix 1g.

Glossary of Ghanaian Mining Laws

With its long history of mining, Ghana has an equally long list of laws, both current and historical, that apply to aspects of small-scale mining (ASM). Ghana is often touted as a leader in mining sector reform, with reforms beginning in the 1980's. The attempts to formalize ASM, however, have not been entirely successful. The majority of artisanal and small-scale mining (ASM) remains informal or semi-formal, often with important environmental and health effects.[1] The major laws applicable to ASM are summarized below.

General Mining Laws

The Mercury Ordinance, 1933

The Mercury Ordinance was proclaimed by the government of the Gold Coast colony, banning the sale of mercury to natives. According to Ofosu-Mensah the law was passed by the colonial government as part of an effort to crack down on local gold miners, who were refusing to work in European mines.[2]

The Minerals Ordinance, 1936

The Mineral Ordinance details the conditions under which mining can be conducted in the Gold Coast Colony. In particular it restricts holding a concession to those who were literate and were deemed to possess sufficient income, confers discretionary powers in the governor, limits the buying and selling of minerals, restricts mining under 100 yards from a public space and withholds compensation to workers injured due to their "own misconduct."

The Minerals Act (Act 126), 1962

The Minerals Act of the newly independent Ghana reaffirmed national control of mineral resources (Article 1) and detailed proper use (Article 2). The act also makes a distinction between "stool land", that is community lands vested in a traditional chief, and public lands managed directly by the government. The act also grants the right of pre-emption to the Republic of Ghana for all materials "raised, won or gotten in Ghana" (Article 5).

Minerals and Mining Law (PNDC 153), 1986

Passed by the military government of Flight Lieutenant Jerry Rawlings, the 1986 mining code was intended to modernize and liberalize the mining sector, as part of series of structural adjustment programs (SAP's) undertaken by the Ghanaian government throughout the 1980's.[3] The act reduces the government stake in mining companies to 20% (Article 22), sets the royalty rate between 3 and 12% and provides for greater dispute mechanisms (Article 31). The law also removes many import duties for mine equipment and immigration quotas for workers (Article 27) and as well provides for a number of capital allowances so as to increase the attractiveness of the sector to foreign capital. The act also requires mine operators to reduce pollution (Article 72) but does not require a separate environmental approval to operate.

Mercury Act (PNDC 217), 1989

Repealing the 1933 ban, the act legalizes the possession and use of mercury provided that they do so with government authorization and buy it from a government authorized dealer (Article 1). In particular it grants licensed small-scale miner the right to buy "a reasonable quantity of mercury" from small-scale miners and requires them to make use of it in a way that respects "good mining practices" (Article 4). It also provides penalties for those miners who fail to do so or deal mercury without a license (Article 5). Despite the limitations imposed by the act the selling to and use of mercury by unregistered small-scale miners remains very common and is largely unenforced.[4]

[1] Sadia Mohammed Banchirigah, "Challenges with eradicating illegal mining in Ghana: A perspective from the grassroots" (2008) Resources Policy 33.
[2] Emmanuel Ababio Ofosu-Mensah "Historical overview of traditional and modern gold mining in Ghana" (2011) International Research Journal of Library, Information and Archival Studies 1:1.
[3] Gavin M. Hilson, "Structural Adjustment in Ghana: Assessing the Impacts of Mining-Sector Reform," (2004) Africa Today 51:2.

General Mining Laws (cont.)

Small-Scale Mining Act (PNDC 218), 1989

The Small-Scale mining law was passed to legalize and formalize Ghana's large informal mining sector. The law allows small-scale miners to apply for minerals rights from the Secretary of Lands and Natural Resources (Article 1.1) for a duration of 3 to 5 years (Article 4.1) and declares that license to be non-transferable (Article 7). It also provides for the creation of District Small-Scale Gold Mining Centres (Article 8) to register miners, monitor operations, provide training and submit reports to the Minerals Commission. The act also prohibits the use of explosives (Article 13), limits the purchase of mercury to government authorized dealers (Article 14) and regulates the selling of gold (Article 17). Despite government hopes of limiting illegal mining, it is estimated that around 85% of small-scale miners still operate informally.[4]

Precious Minerals Marketing Corporation Act (PNDC 219), 1989

Also passed in 1989, the act changes the name of the state owned Diamond Marketing Corporation to the Precious Minerals Marketing Corporation and gives it the ability to buy gold from registered small-scale miners. Like the mercury act, enforcement is often lax, with the commission accepting gold from registered and unregistered miners alike.[4]

Mineral Commission Act (Act 450), 1993

The Act lists the functions of the Mineral Commission, Ghana's primary regulatory body for mining activities. These functions include formulating policy on exploration and exploitation, advising the Minister of Mines, monitoring operations and collecting data on mineral resources (Article 1). The rest of the act details the functioning of the Commission including the appointment of members (Article 3) and the powers of the Minister to make regulations (Article 18).

The Minerals and Mining Act (Act 703), 2006

Passed in 2006 to replace the 1986 act, Act 703 is very much in the same vein as its predecessor, seeking to provide favorable conditions for foreign investors. Like previous acts it reaffirms minerals as the property of the state (Article 1), details the concession process (Article 6) and makes the distinction between land title and subsurface rights (Article 9). The act however, does contain some new elements such as reducing royalties to between 3-6% (Article 25) and providing a greater number of tax and customs exemptions for concession holders (Article 29). Unlike past acts, it is more explicit about environmental protection, requiring approval from both the EPA and the Forest Commission before operations can begin (Article 18). Another notable addition is the ability of companies to make 15 years "stability agreements" with the government, which ensure that the concession holder will not be adversely affected by any new legislation that is passed after the concession is granted (Article 48). In terms of small-scale miners, the act is very similar to the PNDC 218, requiring a license to mineral rights, allowing for the establishment of District offices for small-scale mining, controlling mercury and mineral sells, and criminalizing those who buy and sell minerals illegally (Articles 82-99). Finally the act provides for the further regulation of mining activities in the interests of public and environmental health (Article 110).

Land Laws

Constitution of the Republic of Ghana, 1992-Chapter 21: Land and Natural Resources

Approved by a citizen referendum following the restoration of multi-party democracy in 1992, the Ghanaian constitution provides the basic laws of the republic. Of particular note is Chapter 21 which provides an overview of land and resource rights in the country. Most importantly the Constitution draws a distinction between privately-held lands, public lands, and stool and skin lands, which are lands entrusted to traditional authorities in accordance with customary law. Unlike private lands, stool and skin lands cannot me disposed of but must be managed in keeping with traditional practices, with some government oversight. The constitution also outlines the rights and responsibilities of traditional authorities, and the way in which proceeds from these lands are to be divided between the community, the traditional leadership and the government. The Constitution also grants the government exclusive mineral rights and provides for the creation of a Regional Lands Commission to develop and implement regional development plans.

[4]Benjamin A. Teschner, "Small-scale mining in Ghana: The government and the galamsey," (2012). Resources Policy 37.

Land Laws (cont.)

National Land Policy, 1999

The first comprehensive land policy in the nation's history, it seeks to mitigate land conflicts and ensure proper use. The Policy outlines a number of guiding principles, the most important of which are:

- Equitable and reasonable access to land
- Fair access to land and security of tenure
- Polluter Pays for mining and timber operations
- The private sector as an engine of growth subject to land use guidelines
- Community participation in land management
- Land as a common national property held in trust for the people of Ghana

In keeping with these principles the policy outlines the following objectives:

- Ensure sustainable land use
- Protect the rights of landowners and their descendants from becoming landless or tenants on their own landless
- Ensure adequate compensation when government acquires stool land
- Prevent land encroachment and theft
- Ensure continuous education of the general public in land matters

The policy also outlines that decisions with respect to the disposal of land should take into account both its present natural resources and its conservation for future generations. The policy also prohibits extractive activities such as mining in fully protected areas such as parks, while describing all other lands as open for extraction. The policy also prohibits mining in wetlands and lands with primary forest cover. Finally the policy invests in the government the power to intervene in facilitating investors' access to lands, including stool and family held lands.

National Mining Policy, 2010

This policy seeks to outline current government positions on mining as well as future challenges. Of these the most notable are addressing environmental issues, minimizing social conflicts, assisting small-scale miners, ensuring an equitable distribution of economic benefits, attracting more local capital and ensuring adequate public consultation. The policy seeks to balance a favourable regulatory climate with environmental and social protections as well as mediate between large-scale mining and small-scale miners and affected communities. It also discusses the need to encourage and facilitate women's participation in the sector as well as improve occupational health in mining communities. In terms of small-scale miners, the policy pledges to provide them with greater access to finance, simplify the licensing process, reserve of areas for small-scale mining, encourage safer technology, help with the formation of representative associations and improve health and safety. The policy also discusses the need to generate Geo-Data support for both large-scale and small-scale miners as well as the importance of promoting alternative livelihoods in mine affected communities.

Health Laws

Ghana Health Service and Teaching Hospitals Act, 1996 (Act 525)

The act allows for the creation of the Ghana Health Service to operate at a national, district and regional level as well as providing for the creation of state-owned hospitals and health stations.

National Health Insurance Act, 2003 (Act 650)

Passed in 2003, the act establishes a national health insurance scheme to ensure universal access to basic health care. The act describes three forms of permissible insurance schemes: district mutual health insurance, private commercial health insurance and private mutual health insurance (Article 11). The act explains how each of these health schemes operate, and what support they can receive from the National Insurance Fund in the forms of subsidies (Article 33). It also explains how best to provide health care in the case of indigents (Article 38). The act also dictates the conditions for subsidy provision (Article 81) and allows for for-profit private insurance schemes (Article 41).

Health Laws

National Health Insurance Act, 2012 (Act 852)

Similar in many ways to the National Health Insurance Act of 2003, the 2012 act updates it as well as making some key changes. Article 27 requires that employers ensure that their employees are registered, while Article 98 provides greater quality ensurance guarantees. One key change is Article 112 which dissolves the District mutual health insurance schemes, replacing them with private schemes.

Environmental Laws

Environmental Assessment Regulations 1999

Passed in 1999 the act establishes the need for an environmental permit for activities in which the environment is perceived as being at risk (Article 1). For an environmental permit to be given an environmental impact assessment (EIA) must be conducted (Article 3). The act also outlines the elements required for an EIA, including identification of pollution risks, ecological changes, affected flora and fauna and changes to cultural and economic patterns as well as steps towards mitigation and reclamation (Article 14). The act also mandates that a public hearing be held during the EIA process as a form of consultation and that citizens' concerns be incorporated into the final draft (Article 17). It also outlines penalties for failing to comply with environmental regulation, including the suspension of a concession (Article 26). The act defines environmental impact as an act affecting health, personnel safety, biodiversity, habits, customs, cultural heritage or legitimate means of livelihoods, and states that all mining concessions over 10 ha are required to go through the environmental permitting process.

L.I. 1692 Water Use Regulations, 2001

The Water Use Regulation Act invests in the state-run Water Commission the power to make decisions concerning water use, whether they be commercial, industrial, environmental or for the purposes of power generation (Article 1). It all requires users to seek a permit from the Water Commission before water use (Article 1) upon which the public has 3 months to submit objections (Article 3). The Water Commission also has the power to investigate cases to prevent irreparable damage to water resources (Article 5) as well as hold hearings in the case of public opposition (Article 6). The act also gives priority to water use that is in line with "prevailing water policy", is for domestic use or contributes to national development (Article 7). The Commission, in consultation with the EPA, can demand from users an EIA or environmental management plan (Article 12) and can charge permit holders for water use (Article 21). The water costs for mining operations are set at 10.00GH¢/m3.

National Water Policy, 2007

The National Water Policy of Ghana was formulated in 2007 to provide a framework for the sustainable development of the nation's water resources. The policy identifies the different stakeholders involved in water use and water conservation and seeks to negotiate between competing water requirements. As a guiding principle it recognizes water as a finite and vulnerable resource and seeks to adopt the precautionary principle in minimizing activities with the potential to negatively affect water resources. In regards to mining it identifies the need to balance between the demands of communities and mining firms in terms of water use, requiring that mining operations develop and implement environmental management systems which take into account impacts on water resources. The policy also identifies anthropogenic climate change as a contributing to water scarcity in the region and prohibits private ownership of water in Ghana.

International Conventions

UNEP Mercury Programme, 2009 (Decision 25/5)

Developed by the Governing Council of the United Nations' Environmental Programme (UNEP), Decision 25/5 discusses the importance of and outlines steps to reduce mercury emissions by national governments. The decision identifies mercury as a chemical of "global concern" due to its negative environmental and human health effects and requests specific measures be implemented to limits its use. It identifies the need for provisions to reduce mercury supply and demand, improve storage facilities, reduce trade in mercury, reduce emissions, remediate contaminated sites, increase awareness of mercury's effects and support capacity building, especially in developing countries. It also recommends conducting awareness raising of mercury-free alternatives and mercury reduction in ASGM communities.

Minamata Convention, 2013

The Minamata Convention on Mercury is an international agreement developed by the UNEP to regulate global mercury emissions and control mercury access. The convention was the result of three years of negotiations following the passing of decision 25/5 by the UNEP Governing Council in 2009, and seeks to meet the criteria outlined by that document. According to Article 1 of the Convention "The objective of this Convention is to protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds." The convention prohibits the export of mercury by the parties without government consent and assurances of proper use (Article 3). It also states that parties will take steps to reduce mercury use in ASGM through education, the promotion of alternative technologies and by providing technical and financial assistance (Article 7). The convention encourages the adoption of "best available techniques" in terms of mercury emissions, releases and disposal (Articles 8, 9 and 11). The convention also requires implementation plans from all parties (Article 20), reporting on measures taken (Article 21) and ratification by member states (Article 30). In Annex C, the convention details the requirements expected of ASGM National Action Plans. These include:

- Seeking to eliminate: whole ore amalgamation, open burning of amalgam, burning in residential areas and cyanide leaching sediments and tailing where mercury has been added
- Formalizing the ASGM sector
- Developing strategies to manage the trade and prevent the diversion of mercury
- Involving stakeholders in the planning process
- Addressing the public health aspect of mercury exposure in communities and among miners
- Addressing the effects on vulnerable populations especially children and women of child-bearing age

Appendix 2. List of students and trainees involved in IA at the University of Michigan

- Name (affiliation during involvement)
    - Rachel Long (undergraduate, LSA)
    - Codi Sharp (undergraduate, LSA)
    - Allison Yee (undergraduate, LSA)
    - Allyson Green (MS, Environmental Health Sciences)
    - Dr. Mozhgon Rajaee (MS, MPH, PhD, Environmental Health Sciences)
    - Jing Kaylee Lu (MPH, Epidemiology)
    - Austin Waara (undergraduate, LSA)
    - Rebecca Brewster (undergraduate, LSA)
    - Margaret Goelz (undergraduate, LSA)
    - Dr. Lauretta Ovadje (postdoc, PARTNER II)
    - Dr. Benedict Calys-Tagoe (postdoc, PARTNER II)
    - Dr. Eric Odei (postdoc, PARTNER II)

Appendix 3. IA Team

Natural Science Workgroup

Workgroup Co-Leaders

- Principal Investigator: Nil Basu, PhD
  - Associate Professor, McGill University (formerly University of Michigan School of Public Health)
- Samuel Obiri
  - Water Research Institute- CSIR
  - Co-leader of Natural Science Workgroup; also a member of the Human Health Workgroup
- Mozhgon Rajaee
  - PhD Candidate, Environmental Health Sciences, UM School of Public Health
  - Co-leader of Natural Science Workgroup
  - Also a member of the Human Health Workgroup

Workgroup Members

- Edward Antwi
  - Centre for Energy, Environment, and Sustainable Development (CEESD), Department of Mechanical Engineering, Kumasi Polytechnic
- Samuel Cobbina
  - University for Development Studies
- Edward Kwaansa-Ansah
  - Kwame Nkrumah University of Science and Technology
  - Also a member of the Human Health workgroup
- Vincent Nartey, PhD
  - Professor of Chemistry, University of Ghana, Legon
- Kenneth Pelig-Ba, PhD
  - Faculty of Applied Sciences, University for Development Studies, Navrongo
  - Also a member of the Human Health Workgroup

External Advisers

- David Buck, PhD
  - Tropical Program Director, Biodiversity Research Institute
- David Evers,
  - PhD Biodiversity Research Institute

Social Sciences and Economics Workgroup

Workgroup Co-Leaders

- Principal Investigator: Elisha Renne, PhD
    - Professor and Associate Chair, DAAS, UM Department of Afroamerican and African Studies (DAAS) and Department of Anthropology
- Emmanuel Tenkorang
    - Research Fellow, Institute for Development Studies, University of Cape Coast
- Peter Agyei-Baffour University
    - Lecturer, Kwame Nkrumah University of Science and Technology, Kumasi
- Mark Wilson, ScD
    - Professor of Epidemiology, UM School of Public Health
    - Professor of Ecology and Evolutionary Biology
    - Also a member of the Human Health Workgroup

Workgroup Members

- Ofosu-Mensah Ababio
    - Lecturer, University of Ghana, Legon
- Simon Atebiya
    - Ministry of Lands and Resources
- Samuel Ntewusu, PhD
    - Institute of African Studies, University of Ghana, Legon
- Anthony Osei-Fosu
    - Kwame Nkrumah University of Science and Technology

External Advisers

- Carla Roncoli, PhD
    - Emory University
- Susan Keane
    - Natural Resources Defense Council

Human Health Workgroup

Workgroup Co-Leaders

- Edith Clarke, MD
    - Director, Occupational and Environmental Health, Ghana Health Service
- Tom Robins, MD, MPH
    - Professor of Occupational and Environmental Medicine, Director of Global Public Health, UM School of Public Health, Director, Fogarty International Center Southern African Program in Environmental and Occupational Health

Workgroup Members

- Emmanuel Amoah, MD
    - Medical Officer, Ghana Health Service
- Mawuli Dzodzomenyo, PhD
    - Professor, Department of Biological, Environmental and Occupational Health Sciences, School of Public Health, University of Ghana, Legon
- Eric Odei, MD
    - Public Health Physician Specialist, Ghana Health Service
- Lauretta Ovadje
    - Postdoctoral Researcher, Department of Environmental Health Sciences, UM School of Public Health
- Benedict Calys-Tagoe, MD
    - Public Health Physician Specialist, Korle Bu Teaching Hospital/Ministry of Health
- Reginald Quansah, PhD
    - Postdoctoral Researcher, University of Oulu
- Principle Investigator: Richard Neitzel
    - Assistant Professor, Department of Environmental Health Sciences, UM School of Public Health

External Adviser

- Laurie Chan, PhD
    - University of Ottawa

Project Manager

- Rachel Long
    - Environmental Health Sciences, UM School of Public Health

Appendix 4. Timeline of IA activities

2012	
Quarter 1 (Jan-Mar) **Quarter 2 (Apr-Jun)**	Pre-organization
Quarter 3 (Jul-Sep)	Meeting #1 Finalize group membership Define research questions Establish timelines (data aggregation, preparation; recruitment of all workgroup members), Delegate responsibilities/tasks Evaluate Meeting #1 and IA process Data aggregation initiated by group and individuals
Quarter 4 (Oct-Dec)	Data aggregation, analysis, synthesis by group and individuals; quarterly conference calls to track progress
2013	
Quarter 1 (Jan-Mar)	Data aggregation, analysis, synthesis by group and individuals; quarterly conference calls to track progress
Quarter 2 (Apr-Jun)	Meeting #2 Prepare, synthesize, and present datasets gathered in Year #1 Evaluate Meeting #2 and IA process Develop web-accessible database Data analysis and synthesis Begin development of publications
Quarter 3 (Jul-Sep) **Quarter 4 (Oct-Dec)**	Data analysis and synthesis; updates and regular communication by all members; quarterly conference calls to track progress
2014	
Quarter 1 (Jan-Mar)	Data analysis and synthesis; conference calls to track progress
Quarter 2 (Apr-Jun)	Meeting #3 Presentation of synthesis reports and evaluation of response options Finalize manuscripts and synthesis reports Evaluate Meeting #3 and IA process
Quarter 3 (Jul-Sep)	Data analysis and synthesis; quarterly conference calls to track progress
Quarter 4 (Oct-Dec)	Finalize manuscripts for submission in Jan/Feb 2015
2015	
Quarter 1 (Jan-Mar)	Meeting with policymakers/stakeholders in Ghana Evaluate meeting and IA process
Quarter 2 (Apr-Jun)	Finalize publications

Appendix 5. Main research questions

Economics and Policy Workgroup Research Questions/Topics

- What are the direct and indirect, macro- and micro-economic benefits and burdens of small scale mining (SSM) at the level of families, communities, regions and the country?
- Has past or existing policy been directed at SSMs and economic development, and if so to what extent have these policies affected benefits and burdens?
- What is the evidence base for existing SSM policies and what additional evidence is needed to inform new policy or policy changes?
- In what ways might policy recommendations differ according to short- vs. long-term concerns, and efforts to alter impacts on benefits and burdens?

Human Health Workgroup Research Questions/Topics

- Respiratory disease: How common is it? How does crystalline silica vary in ore?
- What are regional variations in metals in ore, water; biomarkers; etc.?
- What is the interaction among water and multiple stressors (Hg, malnutrition, noise, etc.)?
- Risk perception- injuries, snakebites, health care access, water, etc.
- Noise in mining communities
- General health status of mining communities vs. other communities (malaria, nutrition, etc.)
- To what extent will climate change impact water and mining?
- Number of accidents/injuries in mines; what are key types?
- For above- how does this very by mothers, children, elderly, miners (galamsey vs. legal)?
- What variation exists among different subsets of the population?

Natural Science Workgroup Research Questions/Topics

Main workgroup research question:

- What are the causes, consequences, and correctives of ecological degradation and waste management in small-scale gold mining?

Research sub-questions:

- What are the spatial and temporal trends in deforestation and land use, and implications on the local ecology and hydrology of small-scale mining areas?

- How is mining plastic, solid, and liquid waste managed in small-scale gold mining communities?
- What is the extent and trends of heavy metal contamination in soil, water, sediment, food crops, flora, and fauna from small-scale mining?
- What is the state of water quality parameters (pH, TSS, BOD, COD, DO, etc.) and the implications on aquatic organisms and residents of small-scale mining communities?

Social Science Workgroup Research Questions/Topics

Main workgroup research question:

- What are the social connections between small-scale gold mining, corporate gold-mining for community health and the environment?

Research sub-questions:

- What is the relationship between Chinese mining enterprises (including technology) and small-scale mining? What are the effects of operations on the environment?
- What are the roles of traditional institutions in providing access to land for small-scale gold-mining as opposed to large-scale mines in relation to the federal Minerals Commission's rules pertaining to mining regimes?
- What are the relationships between corporate gold-mining and small-scale gold-miners?
- What are the connections between corporate gold-mining and communities regarding health?
- What is the relationship between the Minerals Commission and small-scale gold miners?
- What are the migration patterns between established large-scale gold mines and small-scale mining communities and their implications for gold mining technology, the environment, and health?

Appendix 6. Meeting and IA process evaluations

Appendix 6a: Meeting #1 evaluation

IA Process and Meeting #1 Evaluation
Summary of evaluation conducted August 7, 2013
Meeting #1 of the Integrated Assessment of ASGM in Ghana
Yiri Lodge, University of Ghana-Legon

Results of quantitative questions:
Participants were asked to rate the following criteria using the following scale: *5 = Excellent, 4 = Very Good, 3 = Good, 2 = Fair, 1= Poor* The averages of ratings are below.

- Clear communication of project goals, activities, and timeline: 4.3
- Organization of planning process: 4.3
- Inclusion of appropriate stakeholders: 3.7
- Value in addressing the problem and research questions: 4.3
- Logistics: 4.1
- Effectiveness in achieving objectives overall: 4.1
- Effectiveness in deciding workgroup membership: 3.9
- Effectiveness in developing research questions: 4.1
- Effectiveness in setting timelines for IA activities: 4.3
- Effectiveness in delegating responsibilities and establishing follow-up mechanisms: 4.3

Themes in qualitative questions:

Positive aspects of IA process with regard to points above:
- Multidisciplinary/Interdisciplinary:
  - "Diverse multidisciplinary team with representation from 4 distinct groups; participants varying in age/experience bodes well for continuum," "Recognizes complexity of problems, encourages interdisciplinarity that is needed."
- Flexibility and clarity:
  - "Flexibility in theme and approach to expand scope thereby increasing applicability to the situations on the ground," "Clear communication of project goals as well as explanation of the integrated assessment framework," "Very well-organized materials; great group"

How the IA process could be improved with regard to the points above:
- Less rigidity
  - "Can be seen as a linear and inflexible problem. [IA process] should be seen as guideline, but not strict recipe," "I think that collecting data fresh from the field is not inconsistent with IA. After all, IA attempts to diversify sources, perspectives and approaches to solving problems."

Positive aspects of Meeting #1:

- Team
  - "The meeting provided a face to face forum that promoted good interaction… this was key for the start-off of the process," "Team appears collegial and cohesive," "The work groups have the requisite expertise," "People seemed open and willing to contribute. Egos did not get in the way."
- Productivity
  - "Very well-organized and comfortable. Timelines clear but wonder if they will be respected."
  - "Could have gotten a bit farther on some items perhaps, but given the timeframe, and collaborators adjusting to each other's styles, very close to the best that could be done."

How Meeting #1 could have been improved with regard to the points above:

- Determining workgroup members
  - "Workgroup membership difficult to determine except through colleagues, but that limits diversity," "Problem with determining group members, particularly those with data"
- Maintaining momentum
  - "Perhaps (I'm doubtful would truly help) asking people to have spent time drafting responses prior to meeting in order to hit the ground running," "Follow-up to the workgroup leaders after the meeting will help to ensure people stay on-task and aware of deadlines."
- Reimbursement
  - "Everything about meeting was very good except the issue of logistics where those of us from Ghana had to pre finance our trips and accommodation and this money could not be reimbursed at the end of the period."

Appendix 6b. Meeting #2 evaluation

IA Process and Meeting #2 Evaluation

Summary of evaluation conducted April 12, 2013
Meeting #2 of the Integrated Assessment of Water Sustainability, Infrastructural Inequity, and Health in Small-Scale Gold Mining Communities in Ghana
Yiri Lodge, University of Ghana-Legon

<u>Themes in qualitative questions:</u>

Positive aspects of the IA process

- Interaction and discussion:
  - *" Most impressive were the far reach and depth of discussion of this multifaceted, difficult problem among so many disciplinary perspectives."*
- Exchange of knowledge:
  - *"A very informal atmosphere facilitating free exchange of ideas and knowledge"*
- Integration of diverse disciplines:
  - *"The interdisciplinary nature of the groupings and the membership enhances the integration of perspectives and therefore enhances the likelihood of solutions addressing the real problems."*
  - *"The format was great for the exchange of knowledge, but importantly, for making members aware of ties to other workgroups for their research, and integrating members' work."*

How the IA process could be improved:

- Need to involve more diverse stakeholders (especially policy makers):
  - *"In my opinion, the IA process can be improved by engaging the local communities."*
  - *"Inclusion of policy makers during the process could improve ownership and hence facilitate policy dialogue and implementation."*
- Engagement before the meeting:
  - *"Constant contact with the members in the individual groups"*
  - *"More successful pre-meeting engagement would have helped."*
- Mixing of groups:
  - *"Other groups' work should be made available to other groups through email."*
  - *"Perhaps mix groups so that different areas get to know each other."*

Positive aspects of Meeting #2:

- Open and frank discussions; sharing ideas and knowledge:
- *" Great for sharing ideas, for identifying individuals and groups to engage in the future, and to vet ideas collectively"*
- *"Getting to meet and work with group members, exchanging information, [and] hearing about the other panelists' research"*
- Definition of goals and timelines:

- *"Timeline, strategies for the next meeting was rolled out in a fairly good way/manner."*
- *"The meeting has helped to define clearly the goals and objectives of the various workgroups."*

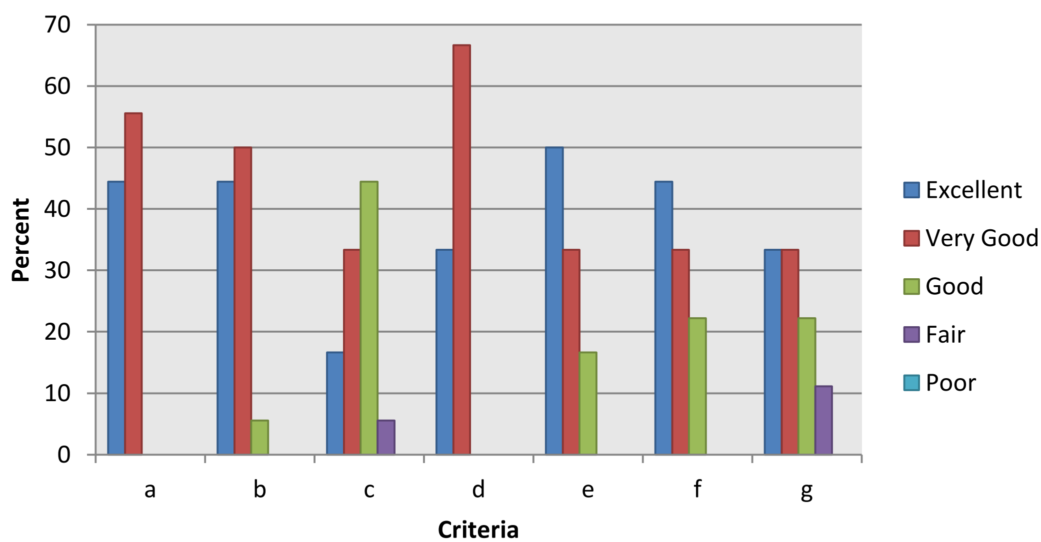
How Meeting #2 could be improved:

- More engagement of stakeholders:
  - *"More rigorous follow-up to these stakeholders who are to be part of the meeting"*
- More mixing among groups:
  - *"Interconnection of groups, i.e. group mixing"*
  - *"... encouraging interaction and knowledge exchange between the various groups"*
- More time:
  - *"Time allotted for the workgroup meetings should be extended."*
  - *"More time should have been devoted to allow for longer deliberations."*

Other comments about the IA process thus far or about Meeting #2:

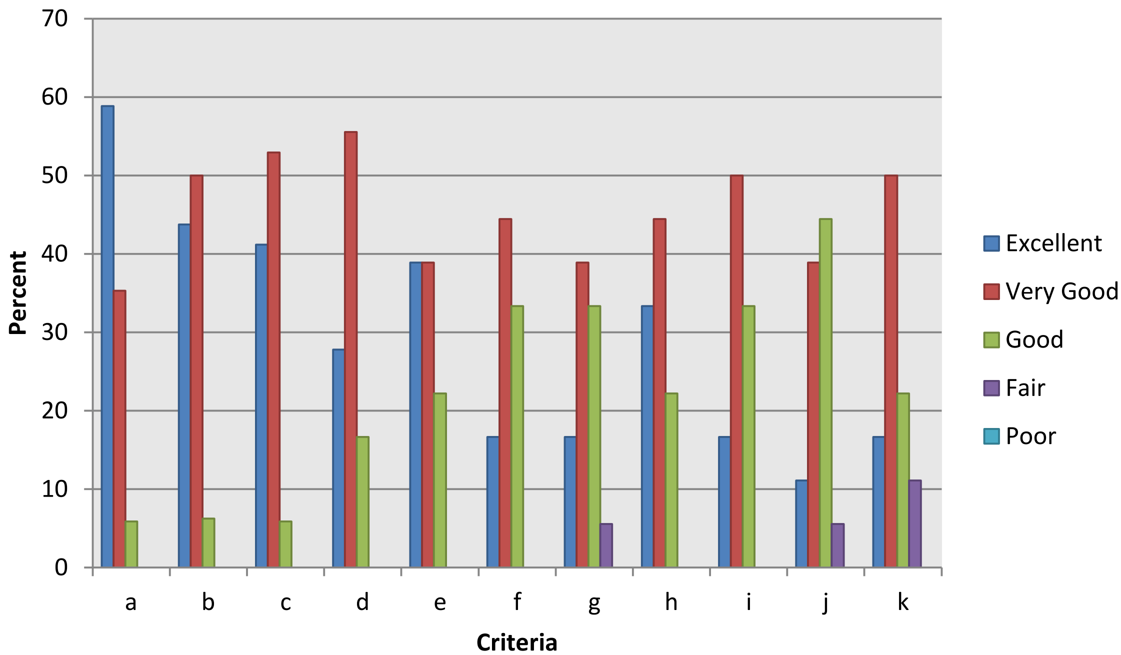
- *"It is a laudable initiative that not only seeks to influence policy decisions on small-scale mining, but also to encourage research in Ghana."*
- *"Engage small-scale mining group leaders."*
- *"Amazingly warm and dedicated group of people"*

<u>Results of quantitative questions:</u>



a. Clear communication of project goals, activities, and timeline; b. Organization of planning process; c. Inclusion of appropriate stakeholders; d. Value in addressing the problem and research questions; e. Exchange of knowledge; f. Formation of partnerships; g. Integration among diverse stakeholders/experts

Fig. 1. Percent of respondents who rated the above aspects of the IA process as "excellent," "very good," "good," "fair," or "poor"



a. Logistics; b. Effectiveness in achieving objectives overall; c. Presentations during Meeting #2; d. Effectiveness in presenting and discussing research being contributed to IA; e. Effectiveness in identifying knowledge gaps; f. Effectiveness in identifying untapped datasets and/or potential additional workgroup members; g. Effectiveness in planning workgroup-specific synthesis paper; h. Effectiveness in brainstorming other project outputs beyond academic papers; i. Effectiveness in creating plans for Meeting #3 (identifying attendees, etc.); j. Effectiveness in setting timeliness for IA activities (Meeting #3, publication deadlines, etc.); k. Effectiveness in delegating responsibilities and establishing follow-up mechanisms

Fig. 2. Percent of respondents who rated the above aspects of Meeting #2 as "excellent," "very good," "good," "fair," or "poor"

Appendix 6c. Meeting #3 evaluation

IA Process and Meeting #3 Evaluation

Summary of evaluation conducted April 30, 2014
Meeting #3 of the Integrated Assessment of ASGM in Ghana
Yiri Lodge, University of Ghana-Legon

Themes in qualitative questions:

Positive aspects of the IA process

- Interaction and discussion:
  - *"This meeting provided a great forum for all members to come together and voice their ideas and opinions."*
  - *"It was a great forum for the interaction of ideas and concepts from the different sectors."*
- Exchange of knowledge:
  - *"... the exchange of knowledge has been excellent."*
  - *"The process of knowledge exchange and formation of partnerships in arriving at the goals of the project is worth mentioning."*
- Diverse disciplines represented:
  - *"There has been a broad base representation that helped to produce a broad base discussing for addressing pertinent issues."*
  - *"Multi-disciplinary nature set the background for learning among the different workgroups."*
  - *"The IA process brought together like-minded researchers from diverse backgrounds and this was very useful."*
- Good organization:
  - *"The process was well-planned, communicated, and executed in order to achieve the desired objectives."*
  - *"Meeting was informative and very well-organized."*

How the IA process could be improved:

- Clearer communication of goals:
  - *"It seems some goals of workgroup IAs vary- need to be communicated again, clearly."*
  - *"Clearly stated goals with clear outputs."*
- More diverse stakeholders:
  - *"More stakeholders e.g. the ministerial task force on mining need to be reached."*
  - *"Find ways to engage stakeholders. Make explicit the kinds of partnerships that are possible, desirable."*
  - *"More actors including members from the District Assemblies, and the health services should be included to solicit their knowledge about small-scale mining."*
  - *"A mining engineer and probably someone from the mining sector in Ghana should have been included in the process. Also, a policy person familiar with the local process of developing policy."*

  - *"The clear thing that is missing is the voice of the miners themselves. It is important to find key representatives/spokesperson who can speak on behalf of one interest of the miners/operators."*
- More time:
  - *"I think the activities were too packed and next time if some these can be done over relatively longer periods."*
  - *"More time should be allowed for discussion."*

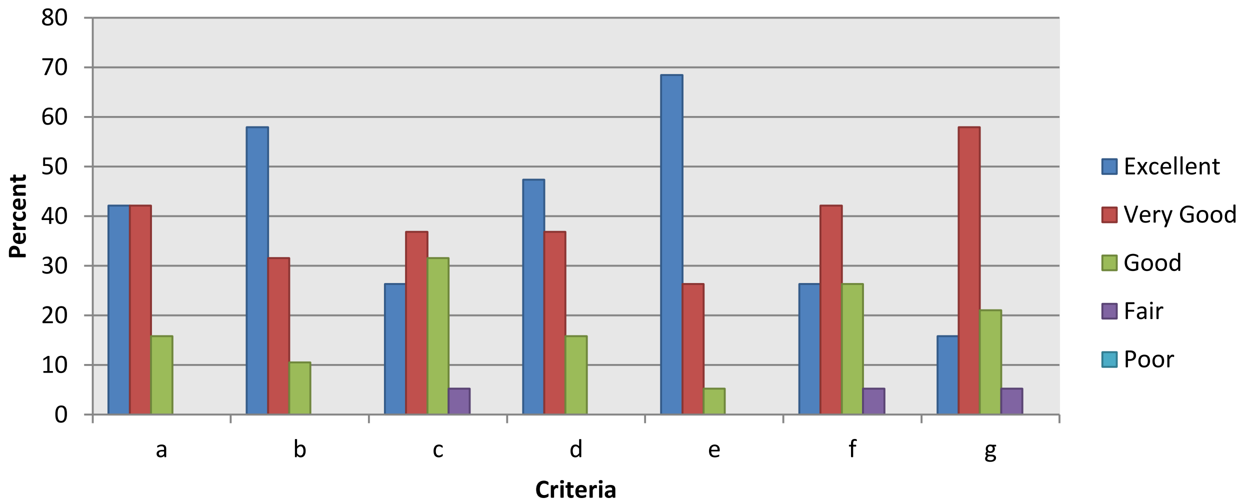
Positive aspects of Meeting #3:
- Polls:
  - *"Very comprehensive statistical data about polls."*
  - *"The process of getting options through the series of polls has been excellent."*
  - *"The poll strategy was very effective in getting the thoughts of individuals synthesized despite the short period available."*
- Brainstorming sessions:
  - *"Brainstorming on issues has also been well-conducted."*
- Interactions and discussions:
  - *"People openly discussed ideas and respected each other's opinions. Was a sense that people were open to new ways of looking at things."*
  - *"Experiences shared from their sectors/people were very practical."*

How Meeting #3 could be improved:
- More time:
  - *"There wasn't enough time to discuss timelines/plans."*
  - *"Time for each presentation should be increased to elicit extensively detailed information from groups."*
- Greater clarity on the response options:
  - *"Options need to be informed by some key considerations and should have been agreed upon by various workgroups."*
  - *"We needed a clearer resolution of options preferred by group and integration of related options."*
  - *"The options were quite confusing during the poll. Took a long time during the workshop to re-define the options."*

Other comments about the IA process thus far or about Meeting #3:
- *"I worry about limiting the number of options too much... In reducing the number of response options too much, we may be ignoring important issues that aren't general/applicable to all workgroups."*
- *"The recommendation/suggestions need to be refined so that they will become briefing notes with background information to be provided to the policy-makers. Very important to find and channel to communicate directing to the Task Force of ASGM. Need to find a leader/spokesperson in Ghana to represent the position of the group..."*
- *"On the whole, organization has been perfect and level of involvement of many individuals has been encouraging."*

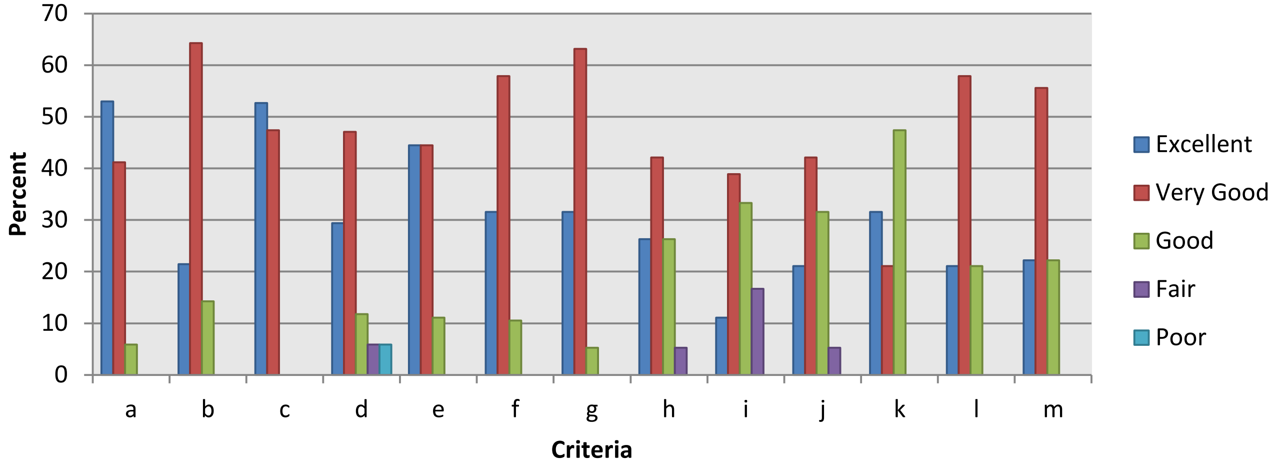
- *"Development of policy-briefs from the outcome of the IA process. Development clear communication channels to communicate the project results to policymakers, ASGM operators, regulators, media, and CSOs."*
- *"The meeting has been very effective."*
- *"The organization has been fantastic, especially the poll system and process."*
- *"Clearly outlined objectives from the start of process. Inclusion of key stakeholders."*
- *"1) I think it was well-organized; 2) Should be the beginning for greater interaction and formation of partnerships for new projects."*

<u>Results of quantitative questions:</u>



a. Clear communication of project goals, activities, and timeline; b. Organization of planning process; c. Inclusion of appropriate stakeholders; d. Value in addressing the problem and research questions; e. Exchange of knowledge; f. Formation of partnerships; g. Integration among diverse stakeholders/experts

Fig. 1. Percent of respondents who rated the above aspects of the IA process as "excellent," "very good," "good," "fair," or "poor"



a. Logistics; b. Effectiveness in achieving objectives overall; c. Presentations during Meeting #3; d. Effectiveness of presentations of workgroup IA report results; e. Effectiveness of presentations of response options; f. Effectiveness of refining and evaluating response options overall; g. Effectiveness of in-person discussions in evaluating response options; h. Effectiveness of electronic polls in evaluating response options; i. Effectiveness in planning workgroup-specific synthesis papers; j. Effectiveness in brainstorming other project outputs beyond academic papers; k. Effectiveness in creating plans for next steps; l. Effectiveness in setting timelines for IA activities; m. Effectiveness in delegating responsibilities and establishing follow-up mechanisms

Fig. 2. Percent of respondents who rated the above aspects of Meeting #2 as "excellent," "very good," "good," "fair," or "poor"

Appendix 7. Presentations made during Meeting #2

Natural Science Workgroup

Life cycle impact assessment of environmental impact assessment of artisanal mining in Ghana: a case study of Dunkwa
Samuel Obiri, Edward Antwi, Niladri Basu, Mozhgon Rajaee, O.D. Ansa-Ansare, F.A. Armah, Samuel J. Cobbina

Artisanal mining and the quality of water from River Mediabewu in Krobiso in Eastern Region of Ghana
D.A. Anang, Edward Antwi, Samuel Obiri

Studies on the mercury-selenium interaction in some parts of the lower Pra River
Vincent Nartey, Raphael K. Klake

The potential effect of mining on water quality in Tarkwa Nsuaem municipality in Western Region, Ghana
Mawuli Dzodzomenyo, Millicent Asare, H. Noye-Nortey, Isabella Quakyi

Determination of mercury, arsenic, cadmium, copper, cyanide, lead and zinc in water bodies Nangodi a small – scale mining community in the Nabdam District, Upper East Region, Ghana
Samuel Jerry Cobbina, Samuel Obiri, J.Z. Dagben

Arsenic, mercury, cadmium, cobalt, copper, lead, zinc and manganese levels in blood serum and whole blood of 300 resident adults from mining and non-mining communities in Ghana
Samuel Obiri, P.O. Yeboah, Shiloh Osae, D. Carboo

Multimedia exposure assessment of mercury in a small-scale gold mining community in Northeast Ghana
Mozhgon Rajaee, Rachel Long, Mark L. Wilson, Thomas G. Robins, Elisha P. Renne, Niladri Basu

Social Science Workgroup

Engagement from Within and Without: A historical analysis of mining in Bole, Northern Region
Samuel Ntewusu

Mining and its consequences in Akyem Abuakwa
Ababio Emmanuel Ofosu-Mensah

Intersecting worlds: small-scale/industrial gold-mining, miner migration, and knowledge transfer
Elisha P. Renne

Illegal small-scale mining in Ghana: a protest of tradition against modernity?
Emmanuel Tenkorang

Water values in a Ghanaian small-scale gold mining community

An Integrated Assessment of Artisanal and Small-Scale Gold Mining in Ghana (ASGM): Final Report

Rachel Long, Elisha P. Renne, Thomas G. Robins, Mark L. Wilson, Kenneth Pelig-Ba, Mozhgon Rajaee, Allison Yee, Elizabeth Koomson, Codi Sharp, Jing Lu, Niladri Basu

Human Health Workgroup

A review of reported injuries from small-scale mining in Ghana
Edith Clarke, Emmanuel K-Amoah

Heavy metal toxicity in the Ayanfuri cluster of Mining Communities, Ghana
Eric Odei, Edith Clarke

Mercury exposure among miners in an artisanal gold mining community in Ashanti Region of Ghana
Edward Ebow Kwaansa-Ansah, Osei Akoto, Niladri Basu

Mercury exposure, blood pressure and lung function in a small-scale gold mining community in northeast Ghana
Mozhgon Rajaee, Allison K. Yee, Rachel Long, Thomas G. Robins, Mark L. Wilson, Elisha P. Renne, Niladri Basu

Human health risk assessment and disease profile from exposure to toxic chemicals in water bodies by artisanal miners in Bogoso in Prestea Huni Valley District, Ghana
Samuel Obiri, Samuel Jerry Cobbina, F.A. Armah, Edward Antwi, B. Ason

Policy and Economics Workgroup

Understanding health risks in small-scale gold mining communities of Ghana: analytic approaches to inform policy
Mark Wilson

Illegal mining in Ghana and the environment
Simon Atebiya

Assessment of inequalities in the livelihood between mining and non-mining workers in mining economy
Anthony Osei-Fosu, Peter Agyei-Baffour

Impact assessment of health infrastructure projects undertaken by Gold Fields Ghana Ltd. at its Damang and Tarkwa sites in Western Region of Ghana
Anthony Osei-Fosu, Kwadwo Afriyie, Peter Dwumah

Economic burden of public health externalities associated with small-scale mining in the Amansie West District of Ghana
Peter Agyei-Baffour, Anthony Osei-Fosu, J. Appiah Nrkumah, KJ Opoku Afriyie

Appendix 8. Response options developed and evaluated by IA team

Response options for first Delphi poll
It is recommended that...
A: ... leaders in Ghana engage in long-term planning and policymaking that addresses the unique challenges of ASGM.
B: ... social support for families in ASGM communities, particularly children and women, be increased.
C: ... employment opportunities available to persons in ASGM areas be diversified.
D: ... provision of basic services in ASGM communities (e.g., electricity, safe water, sanitation, health care) be increased.
E: ... Fair Trade Gold programs and initiatives be developed and implemented.
F: ... ASGM activities be physically separated from residential areas.
G: ... gold be obtained using mercury-free methods.
H: ... gold harvesting be conducted in a common, licensed facility with appropriate control technologies (e.g., mercury-capture, ventilation).
I: ... land reclamation be required after ASGM activities cease (e.g., returning lands to original contours or an improved state).
J: ... explorations for gold deposits be formalized and include assessment of heavy metals in surrounding ore of potential ASGM sites.
K: ... conditions to help ASGM miners register, regularize, and develop their mining activities be promoted.
L: ... legislation that governs ASGM in Ghana be revisited and revised if necessary, and effectively enforced.
M: ... a forestry initiative to reduce deforestation and land degradation associated with ASGM be implemented.
N: ... government entities provide educational campaigns and training centres for ASGM concession owners and miners, focused on health, safety, and environmental impacts.
O: ... ASGM miners be equipped with personal protective equipment (safety boots, hardhats, masks, hearing protection, etc.)
P: ... the government encourage research into the problems and benefits associated with ASGM, and that long-term implications for ASGM communities be prioritized
Q: ... the appropriate parties in Ghana sign the Minamata Convention and develop a National Action Plan (NAP) that includes mercury monitoring, and also helps link government agencies, policy makers with in-country scientists and the regional/international community.
Response options for second Delphi poll
It is recommended that...
**A: ... a national framework for policy and planning implementation be established (i.e., taskforces, workgroups) that considers stakeholder input.*
B: ... a national monitoring plan for mercury be established that includes inventories and abiotic media.
C: ... zoning requirements to separate mining from residences be enacted.
D: ... the Ghana Health Service increase health care access in ASGM Communities.
E: ... the government provide water, electricity, telecommunications, and sanitation in partnership with enterprises to ASGM communities and other affected communities.
** F: ... registration of small-scale miners be increased by improving the process by, for example, reducing or eliminating fees and localizing registration.*
G: ... local authorities in ASGM communities make special efforts to enforce regulations to prevent child labour and keep kids in school.
H: ... the Minerals Commission, EPA, miners, and universities embark on a study on pilot enforcement and implementation of current ASGM-related laws to assess their effectiveness.
** I: ... ministries, local governments, and District Assemblies promote diversification of economic opportunities.*
** J: ... there be public and private support for education with ASG miners on ecological and human health risks, mercury and metals, mercury reduction strategies and business practices.*
** K: ... the royalties from the proceeds of mining be placed into a central account and directed towards improving health and environment of ASGM communities.*
**L: ... universities, the EPA, and the Minerals Commission explore and implement high-yield mercury free alternatives.*

** Top six response options from the second roll of Delphi polling which were rated in Phase 6.*

Appendix 9. Institutions and organizations represented in stakeholder Delphi Poll

Accra Mining Network
Artisanal and Small-Scale Miners (ASM) Africa Network
Chamber of Mines
Council for Scientific and Industrial Research - Science and Technology Policy Research Institute (CSIR-STEPRI)
Council for Scientific and Industrial Research - Water Research Institute (CSIR-WRI)
Ecological Restoration
Friends of the Nation
Ghana Environmental Protection Agency (EPA)
Ghana Health Service
Ghana National Association of Small Scale Businesses
Institute for Development Studies, University of Cape Coast (IDS,UCC)
McGill University
Ministry of Environment, Science, Technology, and Innovation
Ministry of Health Korle Bu Teaching Hospital (KBTH)
Ministry of Land and Natural Resources
National Development Planning Commission (NDPC)
Natural Resources Defense Council (NRDC)
Solidaridad West Africa
Tarkwa Chamber of Commerce and Industry
Tarkwa Municipal Assembly
University of Ghana
University of Michigan
University of Mines and Technology (UMAT)
Wassa Association of Communities Affected by Mining (WACAM)
Wassa Fiase Traditional Council

Appendix 10. Publications

Papers accepted for publication

Kwaansa-Ansah, E. E.; Basu, N.; Nriagu, J. O. Environmental and occupational exposures to mercury among indigenous people in Dunkwa-On-Offin, a small scale gold mining area in the South-West of Ghana. Bull. Environ. Contam. Toxicol. 2010, 85, 476–80.

Paruchuri, Y.; Siuniak, A.; Johnson, N.; Levin, E.; Mitchell, K.; Goodrich, J. M.; Renne, E. P.; Basu, N. Occupational and environmental mercury exposure among small-scale gold miners in the Talensi-Nabdam District of Ghana's Upper East region. Sci. Total Environ. 2010, 408, 6079–85.

Basu, N.; Nam, D.-H.; Kwansaa-Ansah, E.; Renne, E. P.; Nriagu, J. O. Multiple metals exposure in a small-scale artisanal gold mining community. Environ. Res. 2011, 111, 463–7.

Renne, E.; Basu, N.; Gager, E.; Koomson, E.; Lee, B.; Lee, S.; Leeth, A.; Manigault III, D.; Rajaee, M.; Sajjad, A.; Smith, M.; Yee, A. Women's work, health and the environment in a small-scale mining site in norteastern Ghana. Women Environ. Int. Mag. 2011, 13.

Long, R.; Renne, E.; Robins, T.; Wilson, M.; Pelig-ba, K.; Rajaee, M.; Yee, A.; Koomson, E.; Sharp, C.; Lu, J.; Basu, N. Water Values in a Ghanaian Small-Scale Gold Mining Community. Hum. Organ. 2013, 72, 199–210.

Renne EP. Small-Scale and Industrial Gold Mining Histories in Nangodi, UER, Ghana. Journal of West African History 2015, 1, 71-94.

Ofosu-Mensah A. Title Unknown. Journal of African Historical Studies. 2015. Accepted.

Papers accepted for publication in special edition in IJERPH

Basu, N.; Renne, E.; Long, R. An Integrated Assessment Approach to Address Artisanal and Small-Scale Gold Mining in Ghana. Int. J. Environ. Res. Public Health 2015, 12, 11683–11698.

Basu, N.; Clark, E.; Green, A.; Long, R.; Quansa, R.; Neitzel, R.; Mozhgon, R.; Wilson, M. L.; Chang, L.; Obiri, S.; Fobil, J. Integrated Assessment of Artisanal and Small-Scale Gold Mining in Ghana - Part 1: Human Health Review. Int. J. Environ. Res. Public Health 2015, 12, 5143-5176.

Basu, A.; Phipps, S.; Long, R.; Basu, N. Identification of Response Options to Artisanal and Small-Scale Gold Mining (ASGM) in Ghana via the Delphi Process. Int. J. Environ. Res. Public Health 2015, 12, 11345–11363.

Bortey-Sam, N.; Nakayama, S.; Akoto, O.; Ikenaka, Y.; Fobil, J.; Baidoo, E.; Mizukawa, H.; Ishizuka, M. Accumulation of Heavy Metals and Metalloid in Foodstuffs from Agricultural Soils around Tarkwa Area in Ghana, and Associated Human Health Risks. Int. J. Environ. Res. Public Health 2015, 12, 8811–8827.

Bortey-Sam, N.; Nakayama, S. M. M.; Akoto, O.; Ikenaka, Y. Ecological Risk of Heavy Metals and a Metalloid in Agricultural Soils in Tarkwa , Ghana. 2015, 11448–11465.

Calys-Tagoe, B.; Ovadje, L.; Clarke, E.; Basu, N.; Robins, T. Injury Profiles Associated with Artisanal and Small-Scale Gold Mining in Tarkwa, Ghana. Int. J. Environ. Res. Public Health 2015, 12, 7922–7937.

Cobbina, S.; Duwiejuah, A.; Quansah, R.; Obiri, S.; Bakobie, N. Comparative Assessment of Heavy Metals in Drinking Water Sources in Two Small-Scale Mining Communities in Northern Ghana. Int. J. Environ. Res. Public Health 2015, 12, 10620–10634.

Green, A.; Jones, A.; Sun, K.; Neitzel, R. L. The association between noise, cortisol and heart rate in a small-scale gold mining community - A pilot study. Int. J. Environ. Res. Public Health 2015, 12, 9952–9966.

Kyeremateng-Amoah, E.; Clarke, E. Injuries and ill-health among artisanal and small-scale miners in Ghana. Int. J. Environ. Res. Public Health 2015, 12, 10886–10896.

Long, R.; Sun, K.; Neitzel, R. L. Injury risk factors in a small-scale gold mining community in Ghana's Upper East Region. Int. J. Environ. Res. Public Health 2015, 12, 8744–8761.

Long, R.; Renne, E.; Basu, N. Understanding the Social Context of the ASGM Sector in Ghana: A Qualitative Description of the Demographic, Health, and Nutritional Characteristics of a Small-Scale Gold Mining Community in Ghana. Int. J. Environ. Res. Public Health 2015, 12, 12679–12696.

Rajaee, M.; Long, R.; Renne, E.; Basu, N. Mercury Exposure Assessment and Spatial Distribution in A Ghanaian Small-Scale Gold Mining Community. Int. J. Environ. Res. Public Health 2015, 12, 10755–10782.

Rajaee, M.; Obiri, S.; Green, A.; Long, R.; Cobbina, S.; Nartey, V.; Buck, D.; Antwi, E.; Basu, N. Integrated Assessment of Artisanal and Small-Scale Gold Mining in Ghana - Part 2: Natural Sciences Review. Int. J. Environ. Res. Public Health 2015, 12, 8971-9011.

Rajaee, M.; Sánchez, B.; Renne, E.; Basu, N. An Investigation of Organic and Inorganic Mercury Exposure and Blood Pressure in a Small-Scale Gold Mining Community in Ghana. Int. J. Environ. Res. Public Health 2015, 12, 10020–10038.

Wilson, M. L.; Renne, E. P.; Roncoli, C.; Agyei-Baffour, P.; Tenkorang, E. Y. Integrated Assessment of Artisanal and Small-Scale Gold Mining in Ghana - Part 3: Social Sciences and Economics. Int. J. Environ. Res. Public Health 2015, 12, 8133–8156.

Other submitted publications

Ntewusu, S. Title Unknown. Submitted. 2015.

Tenkorang E. Title Unknown. Submitted. 2015.

Obiri S, Cobbina, SJ, Armah FA, Antwi E, Ason B, Quansah R. Human health risk assessment and disease profile of artisanal miners exposed to toxic chemicals in water and sediments in Prestea Huni Valley District, Ghana. Submitted. 2015.

Obiri et al. Title Unknown. Submitted. 2015.

Appendix 11. Presentations

Long R, Basu N, Phipps S, Basu A. "The Delphi Technique for Developing Responses to Small-Scale Gold Mining," oral presentation at the International Conference on Mercury as a Global Pollutant, 18 Jul 2015.

Long R, Rajaee M, Green A, Neitzel R, Basu N. "Mercury in marine and freshwater fish in Ghana," poster presentation at the International Conference on Mercury as a Global Pollutant, 17 Jun 2015.

Long R, Rajaee M, Green R, Renne E, Neitzel R, Basu N. “Metals in Ecological Media and Human Biomarkers in Ghana: A Review,” poster presentation at the International Society for Exposure Science Annual Meeting, 16 Oct 2014.

Long R, Rajaee M, Renne E, Basu N. "Mercury in Ecological Media and Human Biomarkers in Ghana: A Review," poster presentation at the International Conference on Mercury as a Global Pollutant, 29 July 2013.

Long R, Baffour P, Clarke E, Obiri S, Rajaee M, Tenkorang E, Wilson M, Renne E, Basu N. "An Integrated Assessment of Small-Scale Gold Mining in Ghana," oral presentation at the International Conference on Mercury as a Global Pollutant, 30 July 2013.

Rajaee M, Long R, Yee AK, Robins T, Wilson M, Renne E, Basu N. "Respiratory outcomes and urinary mercury exposure in a small-scale gold mining community in Ghana," poster presentation at the International Conference on Mercury as a Global Pollutant, 29 July 2013.

Rajaee M, Long R, Robins T, Wilson M, Renne E, Basu N. " Mercury exposure and blood pressure in a small-scale gold mining community in Ghana," poster presentation at the International Conference on Mercury as a Global Pollutant, 29 July 2013.

Rajaee M, Long R, Yee AK, Sharp C, Lu JK, Koomson E, Wilson M, Robins T, Renne EP, Basu N. “Multimedia exposure assessment of mercury in a small-scale gold mining community in northeast Ghana,” poster presentation at the International Society for Environmental Epidemiology Conference, 28 Aug 2012.

Rajaee M, Long R, Yee AK, Sharp C, Lu JK, Pelig-Ba K, Robins T, Wilson M, Renne EP, Basu N. “Exposure assessment of mercury in a small-scale gold mining community in northeast Ghana,” poster presentation at the University of Michigan Rackham Centennial Research Symposium, 16 Feb 2012.

Rajaee M, Long R, Yee AK, Sharp C, Lu JK, Pelig-Ba K, Robins T, Wilson M, Renne EP, Basu N. “Exposure assessment of mercury in a small-scale gold mining community in northeast Ghana,” poster presentation at the University of Michigan Student Global Health Day, 11 Nov 2011.