Socioeconomic and environmental assessment of informal artisanal and small-scale mining in Ghana

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ABSTRACT

The socioeconomic and environmental impacts of informal artisanal and small-scale mining (ASM) in Ghana are assessed in this paper. The paper includes a case study of an informal ASM-affected community located in the Western Region of Ghana. A two-phase mixed-method approach consisting of literature reviews, questionnaires, interviews, and water quality assessments was employed. The informal ASM was found to be a significant source of livelihood for many rural people who have few employment alternatives. However, it was observed to promote truancy, child labor, teenage pregnancy, and environmental degradation. Water quality was significantly affected by turbidity, followed by manganese and iron, leading to a water quality index at least 500% higher than the upper limit for potability. The authors describe economic, political, social, regulatory, and technological factors as major drivers for the informal ASM. Formalization of the informal ASM in Ghana could minimize the socioeconomic impacts and ensure environmental performance.

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1. Introduction

The socioeconomic significance of artisanal and small-scale mining (ASM) of precious minerals has been discussed by many authors. It provides employment (Hilson, 2016), supports livelihoods of poor rural populations (Fisher et al., 2009), and contributes to national income (Shen and Gunson, 2006), through taxes, export earnings, and provision of raw materials for local industries (e.g., jewelry industry). According to the World Bank (2013), an estimated 100 million people in the world depend on ASM for livelihood.

Despite the economic gains of ASM, it is known to cause security, safety, and environmental issues such as mercury contamination (Hilson et al., 2007; Serfor-Armah et al., 2005), land degradation (Hentschel et al., 2002), pollution, and harm to biodiversity (Kitula, 2006). It is also reported to cause land disputes and violent confrontations between the artisanal and small-scale miners and large-scale mining firms and/or government security force (Andrew, 2003; Aubynn, 2009). Hentschel et al. (2002) also describe the environmentally dangerous nature of ASM and its associated health and safety consequences for workers and surrounding communities and attribute the issues to lack of knowledge, poor technology, economic restrictions, lack of law enforcement, and inadequate environmental legislation.

ASM has been practiced in Ghana for hundreds of years and continues to be an important economic activity, particularly within remote and poorer areas of the country (Aryee et al., 2003). ASM in Ghana has mainly focused on the production of gold and diamonds. It accounts for more than 30% of total gold produced and is currently the only source of diamond in the country. ASM generates foreign exchange; provides direct and indirect employment, especially in rural communities; provides raw materials for local gold-smiths; and promotes local commerce. The Minerals Commission of Ghana (government regulator), estimates more than one million people are directly involved in registered ASM.

Artisanal and small-scale mining exists in two forms in Ghana: licensed and unlicensed (informal ASM) operations. The informal ASM is locally called galamsey, derived from the English phrase, “gather them and sell.” Formerly, informal ASM involved the utilization of rudimentary tools (e.g., pickaxes, chisels, sluices, and pans) and techniques to exploit mineral deposits. The typical mining processes involve digging of mineral-bearing gravels/rocks,
transportation of excavated materials (gravels/rocks), and recovery to obtain the gold for sale. While the digging process commonly results in vegetation destruction, the recovery process typically leads to discharge of contaminated effluents into streams and the natural environment. More recently, the sector has seen gradual mechanization (use of excavators, trucks, dredging machines, crushers, etc.), which has increased the scale of mining with its concomitant environmental, safety, and security issues. This increased scale of informal ASM has resulted in public outcry, with many people calling for a permanent ban on the activities, while the miners call for legitimacy of the informal ASM because it is their only source of livelihood. This view is similar to what was reported by Smith et al. (2016, p.50), who stated that ASM is “reviled by its opponents and romanticized by its proponents.”

Additionally, much of the existing scholarly work has considered socioeconomic and environmental issues of ASM separately. These topics (socioeconomic and environmental issues of ASM) have not been discussed together in a single publication. Accordingly, there is lack of consensus on the way forward. This complex situation has even caused the Ghanaian government to place a temporary ban on ASM activities in the West African country, while authorities explore alternative and sustainable measures to manage the ASM sector. We believe that a holistic assessment presents an opportunity for consensus building towards a sustainable ASM sector whose socioeconomic and environmental impacts are significantly improved. Thus, we perform a comprehensive socioeconomic and environmental assessment of ASM to contribute to the literature and to inform stakeholders’ views and discussions towards an improved ASM. To achieve the goal of the study, a two-phase mixed-method approach comprising of literature reviews, questionnaires, interviews, and water quality assessments was employed. While presenting empirical data from a case study in the Tarkwa mining district of Ghana, where ASM activities are widespread, the study also discusses the situation in other areas where ASM is practiced. As part of its broader impacts, the paper could also serve as a useful reference to guide various governments who are undertaking ASM reforms in their countries.

2. Methods

Relevant literature on factors contributing to ASM and the socioeconomic and environmental effects of ASM were reviewed. Literature was sourced from scientific databases, including Web of Science, and media articles about ASM discourse in Ghana. Empirical data from a case study of a typical ASM community and other ASM areas in Ghana were employed to explore the benefits and problems of ASM. A two-phase mixed-method approach was used to collect data on the socioeconomic and environmental effects of informal artisanal and small-scale mining. Phase one involved acquisition of qualitative and quantitative data through interviews and semi-structured questionnaires. Snowballing and purposive sampling methods were used to select respondents. Phase two included collection of surface water samples, physicochemical analyses of water samples, and acquisition of health and crime data. Water quality index (WQI) technique (Ashun and Bansah, 2017) was employed to assess the overall quality of the surface waters.

3. Factors contributing to informal ASM

Informal ASM is widespread in Ghana, occurring in eight out of ten regions. It is pervasive in the Western and Eastern regions and occurs in certain areas of the Central, Brong-Ahafo, Ashanti, Northern, Upper East, and Upper West regions. Factors contributing to informal ASM operations in Ghana can broadly be categorized into economic, social, regulatory, technological, and political.

3.1. Economic factors

Even though there is emerging evidence that wealthy individuals in society engage in informal ASM by acting as sponsors and investing in the activities (Hilson and Potter, 2005), informal ASM in many parts of Ghana is largely poverty-driven. Informal ASM has been practiced for more than 100 years as a source of livelihood in many communities without the participation of professionals or affluent people. Andrews (2015) shares views that informal ASM has been practiced for survival for many years in rural communities. Moreover, Banchirigah (2008) indicates that people engage in ASM because there are few income alternatives and attributes increasing informal ASM activities to unemployment. A parlance that has become popular among informal ASM workers in Ghana is, “it is better to die looking for food than to sit and die from hunger.”

Increasing levels of unemployment and poverty have driven many people into informal ASM (Tschakert and Singha, 2007). Hilson and Potter (2005) also cite high unemployment in Ghana as a cause for professionals’, semi-skilled personnel, and university graduates’ engagement in informal ASM. These professionals typically do not directly engage in the mining, but act as sponsors by providing financial or material resources to the miners and buying their products at discounted prices. In certain communities, dislocation of informal farmers by large-scale mining companies has impoverished such farmers (Banchirigah, 2008). These farmers may engage in informal ASM in order to escape poverty and to provide for the needs of their dependents.

3.2. Social factors

Many informal ASM workers see mining as a way of life that existed long before large-scale mining operations (Tschakert and Singha, 2007). Though they are aware of the illegal nature of their operations, they feel marginalized by government and multinational companies who operate on their lands. As a result, they “dig for justice” by operating illegally since they consider the “land they work on as natural entitlement” (Andrews, 2015). Andrews (2015) therefore proposed addressing social injustice and marginalization of operators to minimize informal ASM.

The issues raised by Andrews (2015) are confirmed by informal ASM workers in the Tarkwa-Nsuaem Municipality of Ghana. The miners feel socially excluded because the government leases their lands to large-scale mining companies without directly involving them in the decision process. The resolve to continue operating illegally due to social marginalization could be one of the reasons for which government interventions to end informal ASM have remained unsuccessful.

3.3. Regulatory factors

Regulations on artisanal and small-scale mining in Ghana stipulate the procedure for acquiring a small-scale mining license to operate legally. The license acquisition process is bedeviled by bureaucratic bottlenecks (Hilson and Potter, 2005) and cumbersome and expensive. Many of the miners are poorly educated and have little capital to cover license acquisition costs (Bansah et al., 2018). Additionally, delays in the licensing process undermine efforts by subsistence miners to provide financial and livelihood support for their families (Hilson and Potter, 2005), thus resorting to illegal operations.

Moreover, parcels of land that are assigned to licensed artisanal and small-scale miners lack prospecting data to truly establish the
viability or economic potential of those lands. Tschakert and Singha (2007) argue that lack of guarantee for long-term exploitation forces people to work illegally. Further, the ready market for the sale and purchase of minerals facilitates informal ASM. Due to lack of adequate and effective regulations, illegal operators are able to sell their minerals to buying agents licensed by Precious Minerals Marketing Company (PMMC), which is responsible for the purchasing and marketing of minerals in Ghana.

Inadequate enforcement of existing small-scale mining enactments also contributes to informal ASM. Macdonald et al. (2014) indicate that there is poor enforcement of ASM laws in Ghana. This poor regulatory enforcement has partly been attributed to poor monitoring of ASM operations by authorities, inadequate staffing, and lack of logistics (Bansah et al., 2016; Hilson, 2002).

3.4. Technological factors

In colonial times, miners used rudimentary tools to scoop auriferous gravel and sand from river banks and beds (Aryee et al., 2003; Gbireh et al., 2007). The nature of tools made the work so labor-intensive that informal ASM was practiced on a much smaller scale. More recently, the use of heavy earthmoving equipment and less-expensive, improved mining technology has made the work less labor-intensive and increased the scale of mining.

Currently, informal ASM involves widespread use of excavators, bulldozers, dredging and drilling equipment, and semi-mechanized washing plants. For example, in the heat of security force intervention to clamp down informal ASM in 2014, some miners operated at night by hiring more excavators and lighting systems to facilitate mining and evade the security forces that typically swarm the informal ASM sites during the day (Bansah et al., 2016).

3.5. Political factors

Involvement of political leadership in informal ASM has been a subject of media discussion in Ghana more recently. The Bureau of National Investigations, an internal intelligence agency in Ghana, recently reported political leadership participation in the informal ASM (JoyOnline, 2017a). Increased informal ASM during election years is seen by the Ghanaian public as a strategy by political leadership to win power (The Chronicle, 2016), as they remain quiet while informal ASM workers sometimes work in the open. These public views are consistent with that of Teschner (2012), who attributes the boom in informal ASM to political leniency and lack of government control.

Interactions with police officers suggest deep political influence in the informal ASM activities. Illegal miners arrested by security officers are often commonly released without charge due to instructions from political leadership. Media discussions have focused on political and security officials' involvement in informal ASM in Ghana and have highlighted the release of informal ASM workers without a criminal charge due to instructions from political and security officials (JoyOnline, 2017b).

4. Socioeconomic and environmental impacts of informal ASM

Socioeconomic impact of informal ASM is similar to those of licensed ASM operations (Andrews, 2015; Bansah et al., 2016). Informal ASM provides employment to rural people who lack alternative employable skills. As noted by Banchirigah (2008), a number of rural community people displaced by large-scale mining companies resort to informal ASM for income to support themselves and their families. Informal ASM provides indirect jobs for local goldsmiths, women carriers, panners or washers, carpenters, steel benders, and masons to earn income. Informal ASM also contributes to government revenue as their products are bought by licensed dealers and PMMC.

In contrast, informal ASM is reported to have led to increased instances of prostitution, alcohol abuse, conflicts, and spread of diseases such as HIV/AIDS in host communities (Tschakert and Singha, 2007; Banchirigah, 2008). Carson et al. (2005) state encroachment upon properties, pilfering, and social disruption as issues related to informal ASM. Child participation can lead to truancy and poor performance in education. Conflicts between informal ASM workers and the local community sometimes result in violent confrontations leading to fatalities and injuries (Hilson and McQuilken, 2014).

In 2013, the Ghanaian President recognized the potential security threat of informal ASM and commissioned an inter-ministerial taskforce (drawn from the military, immigration, and police) to crack down on illegal miners. Consequently, over 4500 illegal Chinese miners were deported (The Guardian, 2013). Ghanaian citizens were also arrested while equipment were seized and destroyed. More recently (in 2017), a new security taskforce of more than 400 military and police personnel was commissioned by the government to continue the fight against illegal mining. However, the use of security force often resulted in human rights abuse, loss of capital, and heightened disaffection.

Land degradation, water pollution, mercury contamination, air pollution, and loss of flora and fauna have been identified as major environmental issues of informal ASM (Aryee et al., 2003; Hilson et al., 2007; Serfor-Armah et al., 2005). Landscapes of abandoned unstable piles of soil/rock, excavated pits, and vast areas of barren land (due to excessive vegetation removal and soil disturbance) are common features at informal ASM sites (Fig. 1). Informal ASM
workers, in attempt to mine quickly and evade security forces, leave mine openings (pits) unreclaimed, with those abandoned pits serving as potential fall traps to farmers, hunters, and livestock. In 2010, for example, the Ghanaian media reported the death of two pupils who fell in an abandoned informal ASM pit (Graphic Online, 2010). Abandoned informal ASM pits can also serve as potential breeding zones for mosquitoes, which cause malaria.

The effect of informal ASM on water resources include suspended solids, heavy metals, mercury, and oil and grease contamination. Dredging and washing of alluvial gold in rivers (Fig. 2) have also led to siltation of rivers and streams in areas where the miners operate. The operations also change the course of streams and rivers, depriving downstream users of their only source of water. Babut et al. (2003) reported significant contamination of soil sediments at Dumasi in the Western Region of Ghana as a result of informal ASM. Attua et al. (2014) attributed unacceptable levels of arsenic, mercury, total dissolved solids, and turbidity in the Birim and other smaller rivers in Eastern Region of Ghana to informal ASM. Kusimi et al. (2014) also attributed high suspended sediment loading of the Pra River in Ghana to informal ASM. High sediment loading can cause increased cost of water treatment and supply, and engender migration of fish from the affected waters.

Mercury used for gold amalgamation may end up in rivers, contaminate aquatic life, and affect the food chain. Although few studies have been done on heavy metal levels in fish obtained from informal ASM affected waters, a study conducted by Babut et al. (2003) found elevated mercury levels in fish samples obtained from informal ASM affected streams in the Western Region of Ghana. Another study by Adimado and Baah (2002) found instances of high mercury levels in fish from waters that have been impacted by informal ASM.

5. Case study

5.1. Study area description

Bonsa is located in Tarkwa-Nsuaem Municipal Assembly (TNMA) in the Western Region of Ghana (see Fig. 3). It is about 275 km west of Accra (capital of Ghana) and on latitude 5.18333° N and longitude 2.05° W. The town has an estimated population of 4000 people, and many of these people work as subsistence farmers and miners. It is divided into Bonsa No 1 and Bonsa No 2 by River Bonsa. The area is inundated with informal ASM in and along the river banks, with some mining activities occurring in protected forest zones.

In 1963, Bonsa Tyre Company Limited (BTCL) was established at Bonsa to produce car tires (African Development Bank, 2000), and in 1967, Ghana Rubber Estates Limited (GREL) was established to provide raw materials for BTCL (GREL, 2013). Taysec Construction Company Limited was also hosted at Bonsa in the early 2000s. Presently, Bonsa has a police station, community health center, water treatment plant, and public basic school.

5.2. History of informal ASM at Bonsa

Presently, there is no literature describing the history of Bonsa and galamsey in the community. Information provided in this study was compiled through interactions with community leaders at Bonsa. Two brothers, Opanyin Kwesi Fori and Opanyin Ntsiful Nyowa from Dompim (about 5 miles from Bonsa) relocated to Bonsa to farm along the river bank in the 18th century. Due to the availability of fertile farming lands and the presence of water throughout seasons, more people migrated to Bonsa, increasing the population of the area. The establishment of BTCL and GREL in the 1960s introduced alternative livelihood sources in the community. The companies employed most of the people of Bonsa, and also opened up the community to more people for commercial activities and would later resettle in the town.

By 2002, BTCL and GREL had folded up, rendering the working youth and people jobless. People of the area then resorted to informal ASM. Although some individuals were previously involved in informal ASM, the scale of mining activities increased drastically after the collapse of the companies. Informal ASM increased in 2009, when a series of less-expensive mining equipment was introduced onto the market together with investment by foreign nationals.

5.3. Data collection

5.3.1. Focus group discussions, questionnaires and interviews

Four different focus group discussions involving informal ASM workers, community leaders, health officials, and school officials were conducted. Following the focus group discussions, semi-structured questionnaires and interviews were used to collect data from government officials (police, health, education, and water treatment and supply), local community leaders (chiefs, elders, and opinion leaders), informal ASM workers, school children, traders, farmers, and non-miners at Bonsa who directly or indirectly depend on informal ASM. A combination of snowballing and purposive sampling methods was used to select the participants. With the consent of the interviewee, some of the responses were tape recorded and later transcribed and validated independently by

Fig. 2. Informal ASM workers dredge river beds for gold.
two of the authors. Thematic analysis was used to analyze the qualitative data.

The interviews were conducted between 1st October 2015 and 30th November 2016, and covered 300 participants. Secondary data were collected from the government officials/institutions during those periods. Participant observation was done at informal ASM sites to enable the researchers to become acquainted with work activity of the informal ASM workers. Using pseudonyms, some of the interviewees’ responses have been reported verbatim for illustration.

5.3.2. Water sampling and analyses

Water samples from eight locations (shown in Fig. 3) were obtained from River Bonsa, while one sample (S09) was collected from a tributary that was undisturbed by mining activities. The samples were collected at intervals of 1–1.5 km along the river to cover about 9.5 km. The entire stretch of the river could not be sampled due to budgetary constraints, inaccessibility, and hostility in areas worked by itinerant informal ASM workers.

Water samples were collected into acid-cleaned labeled sampling bottles. Prior to sampling, the sampling bottles were washed in the river three times to further decontaminate the bottles. Physicochemical and heavy metal analyses were conducted on the samples at the environmental laboratory of University of Mines and Technology in Ghana. Water quality parameters analyzed included pH, conductivity, dissolved oxygen (DO), turbidity, color, copper, manganese, cadmium, lead, nickel, potassium, zinc, magnesium, calcium, sodium, chromium, and iron.

Water quality parameters, including pH, conductivity, dissolved oxygen (DO), turbidity, and color were analyzed on arrival at the laboratory. Conductivity, pH, and total dissolved solids were measured using Oyster pH-Conductivity-TDS Meter, while DO was measured with Portable Dissolved Oxygen Meter (HI 9146). LaMotte Smart3 Colorimeter was used to determine turbidity, color, phosphate (PO₄³⁻), sulfate (SO₄²⁻), and chloride (Cl⁻) according to procedures described by the manufacturer in the operator’s manual (LaMotte Company, 2016).

Samples for cation analysis were kept refrigerated at a controlled temperature of 4 °C and analyzed a day later with the atomic absorption spectrometer. Prior to spectrometry analysis, 100 mL of each sample was acidified with 1 mL of 68% concentrated nitric acid. The samples were then filtered using Whatman 42 μm filter membranes. Filtrates were subjected to Varian Atomic Absorption Spectrometer (240FS AAS) for determination of concentrations of copper (Cu), manganese (Mn), cadmium (Cd), lead (Pb), nickel (Ni), potassium (K), zinc (Zn), magnesium (Mg), calcium (Ca), sodium (Na), chromium (Cr), and iron (Fe). Results of water quality analyses were compared with World Health Organization’s (WHO) water quality guidelines, as shown in Tables 1 and 2.

5.3.3. Water quality index

Water quality index (WQI) is a performance measure that aggregates information from different physicochemical and biological parameters into a single value that is used to describe the overall quality of water. Several approaches and scales exist for estimating and interpreting water quality index (House and Ellis, 1987; House, 1989; Pesce and Wunderlin, 2000). To compute WQI, each water quality parameter is assigned a weight (wᵢ) that reflects its relative importance in the overall quality of water (Ashun and Bansah, 2017). Following Ramakrishnaiah et al. (2009) and Lateef (2011), weights ranging from 1 to 5 were assigned to each of the water quality parameters in this study. The relative weight (Wᵢ) of each parameter is then computed using Equation (1) (Ramakrishnaiah et al., 2009):

![Fig. 3. Location of Bonna (Bonna No 1 and Bonna No 2).](image-url)
The quality rating \( q_i \) of each parameter is then obtained using Equation (2). In Equation (2), the ideal value \( V_{10} \) for all the quality parameters was taken as zero (0) except for pH, which has an ideal value of 7.0:

\[
q_i = \frac{(V_i - V_{10})}{(S_i - V_{10})} \times 100%
\]  

where \( V_i \) is the measured value of the ith parameter at a particular sampling point, \( V_{10} \) is the ideal value of the ith parameter in pure water, and \( S_i \) is the water quality standard or threshold value for the ith parameter.

WQI is then computed as the weighted sum of the individual quality ratings (Equation (3)):

\[
WQI = \sum_{i=1}^{n} W_i q_i
\]  

In this study, fourteen (14) water quality parameters (pH, conductivity, TDS, turbidity, Cl⁻, PO₄³⁻, SO₄²⁻, Mn, K, Zn, Mg, Ca, Na, and Fe) were used to estimate the WQI.

### 5.4. Results

This section presents the major findings that emerged from the qualitative and quantitative data analysis. These findings are captured under the following themes:

- employment and livelihood
- children’s education
- crime and social vices
- water contamination
- health issues
- water supply and treatment
- land degradation and food supply

#### 5.4.1. Employment and livelihood

Informal ASM is the major source of livelihood and income for the people at Bonsa. Local community leaders estimate at least 3000 people to be engaged in informal ASM at Bonsa. About 60% of the informal ASM workforce includes people who have migrated from other regions in Ghana to Bonsa for informal ASM. Many of the migrant workers had come from the Volta Region in Ghana, where there are few employment alternatives. At least 8 of every 10 Bonsa youth between the ages of 15 and 35 directly engage in informal ASM.

With poor educational background and lack of alternative employment, many of the people participate in informal ASM to escape poverty and to support their dependents. Informal ASM brings about increased local commerce for traders who otherwise can hardly make income. According to the local community, informal ASM has “restored hope” at Bonsa due to increased economic activities (K. Appiah, personal communication, November 2, 2016).

Income from informal ASM has helped some parents provide for the educational needs of their children, provide shelter for their families, and care for dependents. Many other informal ASM operators and beneficiaries have invested their income in the real estate and transportation sector to derive additional income and to ensure their financial security. Informal ASM is recognized by the local community to have made a significant economic impact in the lives of the Bonsa people by providing employment and yielding substantial and quick incomes.

#### 5.4.2. Children’s education

School-age children participate in informal ASM by carrying...
headloads of excavated materials from a mining location to the processing facilities. Income earned from the informal ASM may be used to pay for school fees or spent on clothing and food. In some instances, children are drawn to the informal ASM by their parents as a result of poverty. The parents save the income earned by the children and use that income to provide for the needs of the children.

Child participation in informal ASM has resulted in lack of interest in education, truancy, poor academic performance, and instances, children are drawn to the informal ASM by their parents used to pay for school fees or spent on clothing and food. In some processing facilities. Income earned from the informal ASM may be headloads of excavated materials from a mining location to the school fees or spent on clothing and food. In some processing facilities. Income earned from the informal ASM may be headloads of excavated materials from a mining location to the

The school children show irresponsible behavior and usually disrespect us because they think that they earn more money than the teachers. They don't come to school; my class has 30 students, and sometimes, they are only 10 students in the class. They get a lot of money from *galamsey*, so they don't respect the teachers. They usually tell us to “take” our school because they are going for *galamsey* (B. Kyei, personal communication, October 13, 2016).

5.4.3. Crime and social vices

Bonsa has seen increased crime and social vices (e.g., theft, teenage pregnancy, drug abuse, destruction of cocoa farms and farmlands, and unsafe abortions) following the surge in informal ASM. Reported crime cases were on average less than three per month before the surge in informal ASM. Crime increased to more than 10 cases every month, and security officials attribute the increase to the increasing number of informal ASM workers in the area. Cases related to theft generally increase during the rainy season when informal ASM activities decline due to increased water levels and flooding. Some of the informal ASM workers then resort to stealing for their survival.

Informal ASM in the community is described by the police as “national security threat,” stressing that several attempts to eject informal ASM workers from mining in or around protected forest zones and vital installations have been unsuccessful:

*Galamsey* is a national security threat; several attempts have failed to stop or control it. National Security has visited the mining sites five times, yet they are operating. The *galamsey* guys often attempt to snatch arms from security personnel, who are involved in the fight against their operations. Some of the workers are hard criminals and thieves; they even refer to some of their sites as “no-man’s land” and they retaliate attempts by security officials to stop them from operating (M. Asamoah, personal communication, October 22, 2016).

5.4.4. Water contamination

Results of water quality analyses (Table 1) indicate high levels of turbidity and aesthetically objectionable color. The discoloration and reduction in aesthetic beauty of the river water can be attributed to the crushing and grinding of gravels along the river banks, excavation, and washing of sediments in the river by informal ASM workers. The mining activities introduce solids and dislodge river sediments that are responsible for the high turbidity. The effects of turbidity are described by some researchers (Alabaster and Lloyd, 2013; Bilotta and Brazier, 2008). Some of these include increased cost of water treatment, decline in fishery resources, and serious ecological degradation of aquatic environments. The main issue with color is making the water aesthetically objectionable, and treating to an acceptable limit can be costly.

The high concentrations of iron and manganese (see Table 2) can be attributed to the local geology of the area, as the rocks are rich in manganese and iron (Kesse, 1985). However, informal ASM activities can cause the release of those heavy metals from their in situ state into the surrounding environments. Water quality parameters, including pH, TDS, Cl$^-$, PO$_4^{3-}$, and SO$_4^{2-}$, were generally within WHO recommended limits. Sample (S09) from the undisturbed tributary shows better water quality than samples from the main Bonsa River. For example, as shown in Table 1, the tributary had turbidity of 17 FAU, while Bonsa River showed turbidity in the orders of 300 FAU. Also, true color of the tributary was 135 TCU, while that of Bonsa River was above 600 TCU.

The water quality index (WQI) results are summarized in Fig. 4 and interpreted based on classifications (Table 3) adopted from Ramakrishnaiah et al. (2009). All eight (8) water samples (S1 to S8) from Bonsa River had WQI values more than 500, indicating that the water is unsuitable for drinking. WQI value of the tributary (S9), which is less affected by anthropogenic activities, was less than 100, suggesting good water quality. The WQI of Bonsa River is mainly influenced by turbidity, Mn, and Fe in the order turbidity > Mn > Fe.

![Fig. 4. Water quality index of Bonsa River and its tributary.](image)

<table>
<thead>
<tr>
<th>Sample</th>
<th>WQI Interpretation</th>
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<tbody>
<tr>
<td>S1</td>
<td>&lt;50</td>
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<td>S2</td>
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<td>200–300</td>
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<tr>
<td>S5</td>
<td>&gt;300</td>
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5.4.5. Health issues

There are aggravated health concerns in the Bonsa community due to increased informal ASM activities. Common health issues include teenage pregnancy and unsafe abortion complications, skin infections, and sexually transmitted infections (STIs). According to health officials, ten to fifteen cases of teenage pregnancy and at least five cases of STIs are recorded monthly at the health facility. Girls who are involved in teenage pregnancy usually engage in unsafe abortions that typically lead to health complications.

Skin infections such as rashes, ringworm, and red itching were attributed to the contamination of Bonsa River by informal ASM
because many of the patients who reported those health issues rely on the river water for bathing, cooking, and other domestic activities (see Fig. 5). Though health officials have made efforts to educate residents on the dangers of using the river water, some locals continue to use the water due to accessibility and lack of money for the purchase of piped or treated water.

5.4.6. Water treatment and supply

Informal ASM has greatly affected the cost of water treatment and supply. The water treatment and supply plant in the community takes its source from Bonsa River, which has been affected by informal ASM activities. Increased turbidity and color has caused an increase in the cost of water treatment and supply due to rising consumption of water treatment reagents and frequent replacement of water treatment facilities. For example, 2–2.5 bags of alum were previously used for treating 900,000 gallons of water per day. The number of bags of alum has increased significantly to 7–10 bags of alum for treating the same quantity of water following the surge in informal ASM. Fig. 6 shows various sections of the water treatment facility within the locality. Frequent siltation of sedimentation tanks results in frequent plant maintenances and shutdowns that affect cost of water treatment and regular supply of water.

5.4.7. Land degradation and food supply

The nomadic nature of informal ASM has resulted in haphazard digging and degradation of soils, arable lands, and forest vegetation, as shown in Fig. 7. The lack of reclamation leaves the soils bare and exposed to agents of erosion, disrupting the soil ecosystem. Abandoned pits pose safety threats and also serve as breeding grounds for mosquitoes. The effects of the degradation include loss of flora, fauna, biological habitats, and ultimately, destruction of biodiversity and reduced food supply.

Subsistence farming has been the major source of food supply within the community. Even though some farmers routinely engage in the informal ASM (for income to support themselves, their dependents and augment their farming activities), thus reducing farm productivity and production, a significant reduction in food supply within the area has been caused by the destruction of farms and farmlands. The destruction of farms and arable lands by the informal ASM has resulted in increased cost of farm produce in the locality. Even though cost of food items depends on seasonal changes, inflation and related factors, residents attribute the increased cost of farm produce at Bonsa mainly to the surge in the informal ASM:

We could buy three tubers of cassava at GHS 2.00. Now, we buy similar sizes and quantity at GHS 8.00 [an increase of 300% in cost of similar quantity or size of farm produce] (Y. Adom, personal communication, October 28, 2016).

6. Discussion

Assessment of the socioeconomic and environmental impacts of Ghana’s informal ASM has been conducted using available scholarly literature and a two-phase mixed method approach for the acquisition of empirical data. Qualitative and quantitative data collected from stakeholders of ASM, government officials/agencies, and local authorities provide evidence of high economic gains with marked socioenvironmental issues.

Evidently, informal ASM makes significant contribution to Ghana’s economy, providing employment and income to many poverty-stricken individuals mostly living in the rural areas where the mining occurs. Informal ASM provides raw materials to local blacksmiths for making jewelry and precious artifacts and creates many indirect jobs for people with few employment alternatives. Accordingly, it is recognized as a means for survival by many rural people who engage in the mining. While agreeing with Andrews (2015) that some people engage in the informal ASM for justice, it is observed in this study that many informal ASM workers at Bonsa largely dig to escape poverty.

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Fig. 5. Turbid Bonsa River and human activities: (a) Children swim in river; (b) Children swim and fetch water for domestic use; (c) Woman washes her clothes in the river while children swim; and (d) Child fetches water for domestic use.
The mining, however, poses alarming threats to the social and physical environments. Increasing socioeconomic and environmental issues such as land degradation, water pollution, destruction of farms/farmlands, spread of water-borne infection, truancy, child labor, teenage pregnancy, theft, and security concerns associated with the informal ASM makes the mining unsustainable. For example, the empirical data from the water quality analysis showed that the water quality index (which was mostly controlled by

Fig. 6. Impact of Informal ASM on Water Treatment: (a) Water at intake source; (b) Water in intake tank; (c) Flocculation chamber; (d) Flocculation chamber after one month; and (e) Dislodged sludge.

Fig. 7. Informal ASM degraded lands in study area.
turbidity, manganese, and iron) was at least 5 times more than the upper limit for potability. The increasing number of children in the informal ASM requires that authorities pay critical attention to informal ASM. Children who engaged in the informal ASM are typically drawn or pushed into the mining activities by their parents or guardians with the main purpose to raise income for their upkeep and education. The factors that drive children into the informal ASM at Bonsa are similar to what is reported in other communities by Ampomah and Gyan (2014) and Hilson (2010), who describe poverty as the major driver for child involvement in the informal ASM.

The Ghanaian government recently intensified the “fight” against informal ASM with the hope to completely stem the mining activities in the country. However, it is observed in this study that until government develops sustainable interventions to economically empower the many poor rural people, informal ASM would continue to thrive no matter the forces that may stand against the workers. Increasing youth unemployment, poverty, lack of alternative employment, and social marginalization could account for the failure of government’s security intervention to end informal ASM in the country over two decades after legalizing artisanal mining through the Small-Scale Gold Mining Law of 1989 (PNDC 218).

In order to minimize the socioeconomic and environmental issues of the informal ASM and to improve the benefits of the sector, authorities can aim at promoting sustainable mining by formalizing the sector. This formalization process should include awareness (education), organizing, regulation, and taxation. Awareness should include education, publicity, and social pressure to bring about a change in the behavior of the informal ASM workers and affected communities. The education will also bring them into the realization of the intensity and severity of the consequences of their activities. Organizing should involve bringing the informal ASM workers together and recognizing their operations by registering them through an inexpensive and less bureaucratic process. The workers can be organized into groups for effective monitoring and control.

Regulation should involve enactment of appropriate laws and enforcement to ensure that mining is conducted in a manner prescribed by law and in accordance with standard practices. Such regulations should be specific, detailed, and envisage potential modifications to ASM in Ghana. It is also expected that adequate trained staff and resources for the regulatory institutions can improve monitoring and enforcement of regulatory enactments. Taxation should be charged appropriately as a means to generate revenue, which can be channeled into developing mining-affected communities. Such taxes could also be used to provide scholarships for the training of the miners on safe and environmentally friendly mining practices, and support the budget for treating water and restoring mine-degraded areas. Biochar has been known to be very effective for the treatment of degraded soils (Maroukine et al., 2017). Authorities can use portions of the taxes to explore an environmentally friendly technique to clean mine-contaminated areas. Thus, reinvesting the proceeds into strategic sectors of the affected communities or adopting payment for ecosystem services (PES).

The authors acknowledge that formalization of the informal ASM sector can be very difficult, but also contend that with commitment, political will, and support from stakeholders, authorities would be able to formalize the informal ASM sector to bring about remarkable socioeconomic development and to improve environmental performance. Such formalization can improve the lives of the many impoverished local people who depend on the informal ASM as their only source of livelihood, generate revenue for government, improve safety, and minimize environmental issues.

7. Conclusion

We observed in this study that informal ASM is a significant source of livelihood for many rural people. However, its marked social and environmental issues such as trancy, child participation, teenage pregnancy, environmental pollution, and security threat are enormous. For example, empirical evidence showed water quality index of at least 500% higher than the upper limit for potability. These problems can be attributed to economic, social, regulatory, technological, and political factors. To improve socioeconomic and environmental performance and to ensure sustainability, the authors propose a comprehensive formalization. The formalization process should include:

- the participation and education of all stakeholders, including the ASM operators
- organizing the ASM operators under a structured system for effective monitoring
- regulation of the mining activities, enactments of appropriate laws, and enforcement
- taxation to generate revenue to help manage ASM and develop affected communities

In the authors’ view, institutional strengthening, political will, involvement, and commitment of all stakeholders could help make the formalization effective and sustainable. A formalized ASM sector can bring about remarkable socioeconomic and environmental performance.

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