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A Survey of Mining and Tailings Disposal Practices of Selected Artisanal and Small Scale Mining Companies in Ghana

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Abstract: Management of small scale mining operations for maximum profitability with good environmental stewardship requires careful planning of mining and tailings disposal strategies. Field studies and observations of eleven selected artisanal and small-scale gold mining companies winning gold from alluvial (placer) source mostly, but also mine out cropping and underground quartz veins where available from the Takwaian and Birimian Formations in southwestern Ghana. Excavation is either by pitting or using backhoes. Sluicing, panning followed by mercury amalgamation and then roasting to recover the gold is the beneficiation method in use. Riverine waste rocks/tailings disposal is the main management invoked, however some companies do sell their waste to construction firms. Environmentally mining operations are impacting rivers with siltation, mercury pollution, channel diversions and possibly change in heavy metals concentration and water chemistry. Vast arable lands are degraded leaving peasant farmers with no livelihood due to failure by concessionaires to reclaim lands after closure. Only two companies out of the eleven somehow demonstrated environmental consciousness by constructing small tailings dam and backfilling some pits.

Keywords: Alluvial, amalgamation, backfilling, gangue minerals, mercury pollution, waste rocks

INTRODUCTION

Small-scale mining is variously defined, but United Nations (1971) defines it as any single unit mining operation having an annual production of unprocessed material of 50,000 tones, or less as measured at the entrance of the mine. Intermediate Technology Development Group (2001) however, emphasis the use of rudimentary tools and techniques (e.g. picks, chisels, sluices and pans) to exploit the mineral deposits. In Ghana according to Aryee *et al*. (2003), small-scale (gold) mining is defined as"…mining (gold) by any method not involving substantial expenditure by an individual or group of persons not exceeding nine in number or by a co-operative society made up of ten or more persons".

The mining activities of some, if not all, Artisanal and Small scale Gold Mining (ASGM) companies currently in Ghana, have been a subject of keen interest and intense debate by the populace, environmental pressure groups and some international agencies due to the negative environmental impact nationwide. ASGM operators normally use amalgamation recovery process as gold beneficiation technique (Donkor *et al*., 2006) because it is very simple, inexpensive and easier to use. ASGM activities are widely practiced in the Western, Eastern, Central, Ashanti and northern part of the country (UNIDO, 1999) notably in Prestea, Tarkwa, Dumasi, Nkawkaw, Kwabeng, Dunkwa, Obuasi, Dompoase, Amansie, Manso-Nkwanta, Konongo etc. mostly in the vicinities of rivers and terrestrial soils. Many people are being attracted into this operation due to the fact that ASGM operations require modest investment and little technical knowledge. Ntibrey (2001) asserts that the types of deposits (quartz reefs, placers, lateritic, etc.) and location determine methods used in mining operations. This helps to compare and explain parameters affecting natural systems (e.g., water) with those affected by human activities like mining.

The disposal of waste rocks/tailings, the composition of which are directly related to the composition of the ore materials, after mining as well as some chemicals for processing the valuable (target)minerals from the gangue minerals, become the most important environmental issues for ASGM practitioners. The oxidations of sulphide rich waste rocks/tailings produce acid mine/rock drainage (Bertrand *et al*., 2000) requiring restorative treatment prior to disposal into the environment. Mercury contamination of the environment (water and soil) is another very important environmental issue.

There are several methods used for waste rocks/tailings disposal (USEPA, 1994), including disposal of dry or thickened tailings in impoundments or free-standing piles, backfilling underground mine workings and open-pits, subaqueous disposal and the

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most common method, the disposal of tailings slurry in impoundments.

Historically, tailings were disposed off where convenient and most cost-effective, often in flowing water or directly into drainages. However, as local concerns arose about sedimentation in downstream watercourses, water use and other issues, mining operations began or otherwise. The environmental implications of the impounding waste rocks/tailings behind earthen dams, which were often constructed of tailings and other waste materials. Though significant pressure is exerted on major mining companies to conform to stringent environmental standards, minor companies especially ASGM operations do not take significant steps to prevent or mitigate environmental damage as a result of their operations. Murray *et al*. (2003) noted that Ok Tediin Papua New Guinea (PNG) had been a controversial operation due to the combined impact of riverine tailings and waste rock disposal.

ASGM operations in Ghana though legalized (PNDC Law 218, 1989) had become unpopular (Aryee *et al*., 2003) due to environmental damages-ecosystem destruction, land degradation, mercury pollution, mass extinction of some exotic biological species, pollution of soils and agriculture sites, etc., (Amegbey *et al*., 1997; Hilson, 2002) that the country has experienced in recent times especially by illegal miners whose operations are not amenable to monitoring. Rainwater acting on piles of waste rocks/tailings had transfer contaminants (heavy metals, mercury, sediments, etc.) to freshwater sources/supplies. Tailings in impoundments leak at some point to the environment. Although there are a number of established legal frameworks to regulate and monitor mining operations in general in Ghana just like any other nation, yet very little had been achieved in this regard. This study describes the operations of some selected ASGM companies and examines if in particular their waste rocks/tailings disposal practices are environmental friendly. The ASGM operations with respect to the type of deposits (quartz reefs, placers, etc.), lithologic units and processing methods adopted and their future effects on, the ecosystem and health status of miners as well inhabitants in communities where such mining activities are on-going are also discussed.

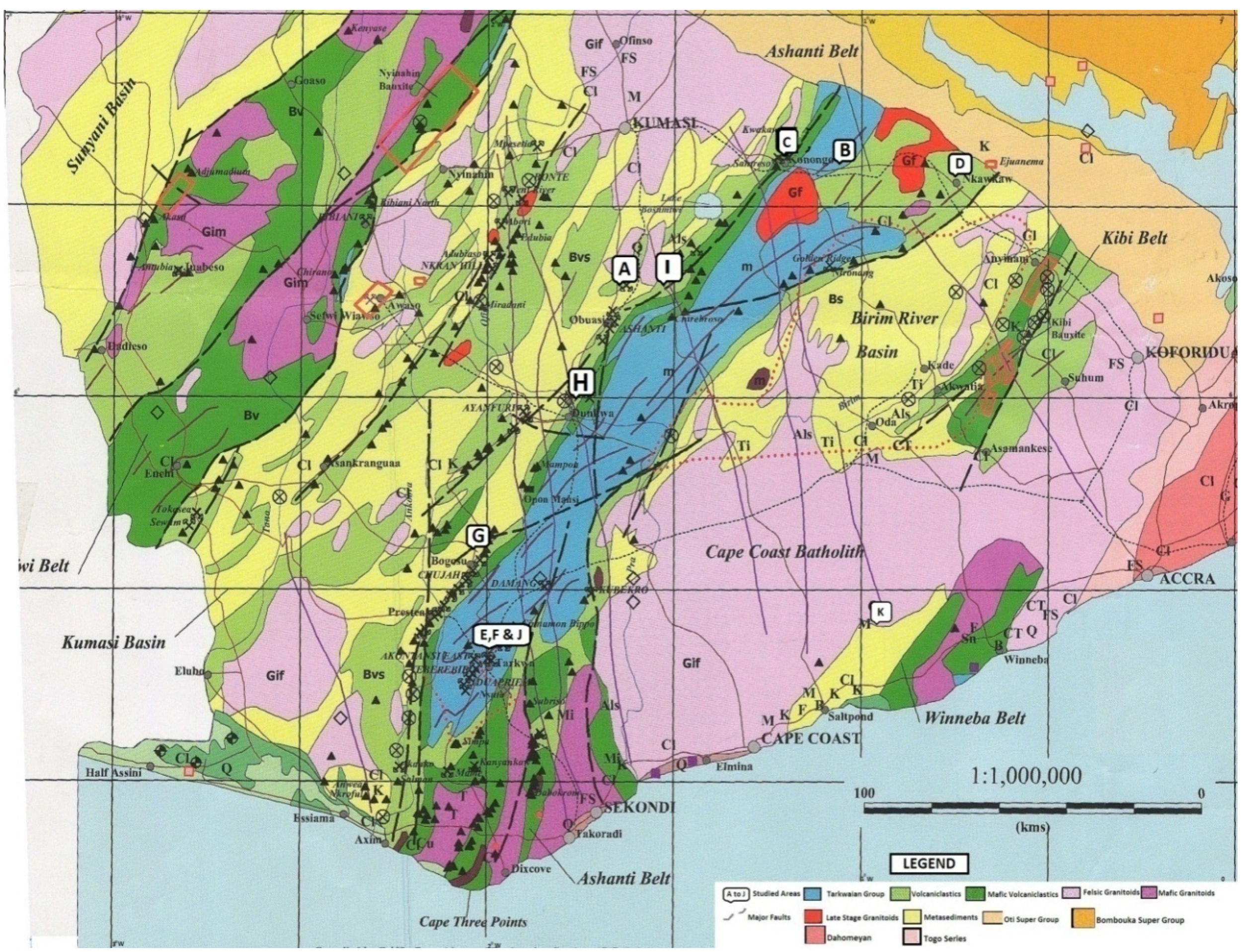

Fig. 1: Map of southwestern Ghana showing locations and geology of studied ASGM operations

FIELD STUDIES

The study areas cover parts of Wassa West District in the mid-southern part of the Western Region with Tarkwa as its administrative capital, some areas near Dunkwa in Central Region, Amansie, Konongo in Ashanti region and Nkawkaw in the Eastern region. These locations are labeled "A to J" in Fig. 1 all within the major gold belt in Ghana. Though there are four types of resources; placer (alluvial), hard rock surface, hard rock underground and tailings from old workings mostly from large-scale mining operations (UNIDO, 1999), placer deposits constitute the main ore of the ASGM operations in the study areas. Occasionally attempt is made to extract surface and underground hard rock quartz vein deposits where available. Operations are normally carried out in ancient as well as current river channels.

Primarily alluvial gold deposits in Ghana are found in the basal gravels in valleys of major river systems

Table 1: Summary of processing and waste/tailings disposal management practices of the studied ASGM operations

Property/location	Mineral mined	Deposit type	Processing	Tailings disposal and management
Company A	Gold	Placer	Mineral extracted by sluicing then concentrated by panning. Mercury is then added to form amalgam.	Waste rocks/tailings are stockpiled and discharges channeled into water bodies. Mercury polluted effluents also discharged into nearby water-bodies.
Company B	Gold	Placer	Mineral extracted by sluicing then concentrated by panning. Mercury is then added to form amalgam.	Waste rocks/tailings are stockpiled and discharges channeled into water bodies. Mercury polluted effluents also discharged into nearby water-bodies.
Company C	Gold	Quartz - Vein	Quartz veins first pulverized to fine materials. Mineral extracted by sluicing then concentrated by panning. Mercury is then added to form amalgam.	Waste rocks/tailings sold to other mining companies while effluents polluted with mercury channeled into nearby water-bodies.
Company D	Gold	Placer	Mineral extracted by sluicing having pulverized over size materials then concentrated by panning. Mercury is then added to form amalgam.	Part of the waste rocks/tailings used to reclaim some of the pits, the rest left scattered around the mining area.
Company E	Gold	Placer and quartz vein	Mineral extracted by sluicing having pulverized over size materials then concentrated by panning. Mercury is then added to form amalgam.	Waste rocks/tailings stockpiled and later sold to construction firms. Waste rocks and treatment effluents flowing to near by water-bodies.
Company F	Gold	Placer and quartz vein	Mineral extracted by sluicing having pulverized over size materials then concentrated by panning. Mercury is then added to form amalgam.	Waste rocks/tailings stockpiled and later sold to construction firms. Waste rocks and treatment effluents flow into nearby water-bodies.
Company G	Gold	Placer (oxidized)	Mineral extracted by sluicing then concentrated by panning. Mercury is then added to form amalgam. The gold obtained by squeezing the amalgam in handkerchiefs.	Waste rocks/tailings left on river beds after extraction.
Company H	Gold	Placer	Mineral extracted by sluicing then concentrated by panning. Mercury is then added to form amalgam. The gold obtained by heating the amalgam over coal pot.	Waste rocks /tailings left on river beds after extraction.
Company I	Gold	Placer	Mineral extracted by sluicing then concentrated by panning. Mercury is then added to form amalgam. The gold obtained by heating the amalgam over coal pot.	Part of the waste rocks/tailings used to reclaim some of the pits, the rest left scattered around the mining area.
Company J	Gold	Underground quartz vein	Hard rock pulverized before sluicing and concentrated by panning. Mercury is then added to form amalgam. The gold obtained by heating the amalgam over coal pot.	Tailings sold to construction firms. Constructed small tailings dam to hold remaining tailings to avoid spread into the environment.
Company K	Gold	Placer	Mineral extracted by sluicing then concentrated by panning. Mercury is then added to form amalgam. The gold obtained by heating the amalgam over coal pot.	Part of tailings used to backfill pits and the rest left on river bed.

and their tributaries (e.g., Ankobra, Offin, Oda, Birim, Jeni, Jimi, Bonte, etc.) draining terrains underlain by meta-sedimentary and meta-volcanic of the Birimian and Tarkwaian Systems (Kesse, 1985). The gravels are overlain by clayey overburden between 1-3 m of average thickness. Overburden, from top to bottom, consists of silty clay, silt and coarse sands containing plant fragments. Normally 0.2-0.3 m of weathered bedrock, immediately below the gravels, most often contain significant gold values. Grades of gold vary along the channel (s). Size distribution of gold grains becomes finer as one progress downstream.

Generally, the bedrocks underlying the areas of operations trend NE-SW (Fig. 1) and have been metamorphosed to the lower greenschist (chlorite-sericite) facies. The meta-volcanic materials in the studied areas consist of Basin-type granitoid complex (biotite-quartz-rich foliated granitic rocks) and Belt-type granitoids (hornblende-rich granitic rocks).

While some operators still use pitting, sluicing, panning, etc. to concentrate the gold, others use semi-mechanized and mechanized methods where backhoes/excavator, trommels and Knelson concentrators are employed to recover gold concentrates from sediments. With hard rocks, jaw crushers, hammer mills, ball mills and modified corn mills are used to pulverize materials before sluicing and panning. The concentrates are then washed off into pans, water is decanted and mercury is added to the very small volume of concentrate obtained. The mercury is rubbed hard into the concentrate until an amalgam (Au/Hg solution) is formed leaving behind the gangue minerals. The gold is finally obtained by roasting.

The tailings comprising gangue minerals, over and under size materials, mercury contaminated water, etc. are disposed off and managed by various methods as specified in Table 1.

RESULTS

A summary of the waste rocks/tailings production, disposal method and management for each of the ASGM operations studied is presented in Table 1. Almost all the studied ASGM operations engaged in reverie tailings disposal by stockpiling in the channels they worked in be it ancient or current. These stockpiles are not protected in any way. A number of these ASGM operators do not reclaim or restore the land to its original or near original state, but rather sell the tailings which ought to have used to backfill excavations. Only three ASGM operations, Company J in Tamso, Company K in Gomoa Ajumako and Company I can be said to be practicing somewhat environmentally friendly operation by constructing a sizeable tailings dam to contain its waste and backfilling some pits/trenches, respectively.

With respect to waste water laden with mercury, all the studied operations channel such contaminated water into river systems, a practice which has serious negative health implications for both workers and social communities within the catchment areas of the ASGM operations.

DISCUSSION

The ASGM tailings comprise of silty to cobble sizes of materials mostly quartz with little or no loamy soil while the waste rocks are admixtures of excavated earth materials. The unprotected and less stable nature of these waste rocks/tailings make them easily spread out to cover large areas of land capable of destroying vegetation of several hectares (UNIDO, 1999) along the rivers or streams. This occurrence renders the previous arable land barren such that these hectares of land cannot be put to any cultivation after the ASGM operators have left the sites. Therefore most peasant farmers in these communities are left without any livelihood.

Disposal sites selection are heavily influenced by costs of transporting the waste rocks/tailings and proximity of deposit to land availability (Murray *et al*., 2003). These challenges the ASGM operators in the studied areas have to grapple with, therefore prefer dumping their waste rocks/tailings in/or close to the river channels where they operate in order to avoid transportation cost. This direct dumping of waste rocks/tailings into surface water-bodies/water-ways often comes with devastating environmental results (Ayree *et al*., 2003; Murray *et al*., 2003; Sweeting and Clark, 2000). During and after the operations of the studied ASGM operators are sceneries of vast lands with unprotected less stable piles of waste rocks/tailings, abandoned un-reclaimed excavations (pits, trenches, etc.) and pools of mostly stagnant water sometimes mercury laden as well as turbid flowing rivers and/or streams in mostly diverted channels (Ayree *et al*., 2003). Drainage of effluents from tailings silts channels of rivers and streams with fine particles, a situation that leads to flooding during raining seasons. Siltation causes increase in turbidity of drainage systems, river bed aggradations (as the sediments settle out of suspension), changes in water chemistry (as metals in the sediments go into solution or form complexes with other materials in the river) and coloration of such waters affect aquatic life and render water unusable for both domestic and industrial purposes. It implies that all dependents on the rivers/streams downstream of the operations of the ASGM operators are at risk of health problems that are associated with the uncontrolled mining. Another threat is acid rock drainage (Da Rosa and Lyon, 1997) that can last for several years after ASGM operators especially those who worked on hard rocks having sulphide materials have left. Contaminations from tailings (heavy metals, mercury, etc.) constitute another mine waste generation.

Even though Company J managed to construct sizeable tailings dam on site, it was not adequate and standard considering the volume (not quantified) of waste generated and the engineering involved. Sweeting and Clark (2000) noted that badly designed dams or dams that are not tailored to the specific geographic conditions of an area can still pose serious environmental risks. The dam and impoundment themselves can displace or damage locally valuable habitats and ecosystems. Waste dumps should be located away from rivers, streams and lakes. If a waste dump must be placed near a surface water resource, then a drainage containment system must be installed to ensure that contaminated drainage does not enter the local water system or groundwater. But the ASGMs in the studied areas do very little to properly contain the tailings from their operations, hence land degradation is on the ascendancy at and around the mining sites. To minimize the chances of erosion, sedimentation and water contamination the excavations ought to be away from drainage systems (rivers, streams, etc.) USAID (1999) so that the rivers/streams do not enter the pits. Where this is not possible, then the river or stream should be diverted, where feasible, to avoid contact with the mining pit. Storm water and groundwater that may inevitably enter the pits must be collected, removed and treated, then reused.

Though considered to be ASGM operations, in reality some of these operations are semi-industrial or fully industrial in character (Hentschel *et al*., 2003) as the degree of mechanization and internal organizations are advanced. Some of the studied operations are most likely being financed and managed by partners from industrialized countries even though information in this regard was not immediately available. The level of mechanization within these operations in most cases, accounts for the sceneries of vast land degradation, even though these ASGM operators are required to close up properly by legislation (Ghana EPA Guidelines, 1999).

Mercury amalgamation is a simple and inexpensive method of gold extraction (Gunson *et al*., 2006), therefore the preferred choice of ASGM operators. All the ASGMs studied use mercury amalgamation for their gold extraction. But this beneficiation method has serious environmental consequences. Rivers and streams are polluted by mercury discharged into them during the amalgamation processes (Miguel, 2000; Obiri, 2005; Essumang *et al*., 2007) by ASGM operators. It has been estimated that for every gram of gold recovered by ASGM operators, significant amount of mercury is released into the environment (USAID, 1999), a situation likely to leave behind permanently ruined habitat which will result in sickness and even death. Various researchers, Babut *et al*. (2003) studied Hg contamination in the Apopre river basin at Dumasi, Bannerman *et al*. (2003) studied Hg and arsenic (As) contamination in sediments and water in Ankobra river basin, Golow and Mingle (2002) and Golow and Adzei (2003) carried out Hg contamination studies in some rivers near Dunkwa-on-Off in and they all concluded that ASGM is one such anthropogenic activity that had impacted rivers with enormous amount of metallic mercury. The inorganic Hg may be converted by microbial activities in an organic rich environment to organic forms of Hg which are extremely toxic to organisms (Beijer and Jernelov, 1979). The use of amalgamation by these ASGM operators for beneficiation poses unique problems in the communities they operate in. The mercury would be absorbed by organisms (humans, etc.) through drinking water, food or breathed air. Thus lack of appropriate technology and proper health and safety procedures by these ASGM operators is indeed a potential recipe for severe environmental degradation, mercury pollution of river systems and adjacent arable lands. Whereas in some countries like Tanzania studies have been conducted to quantify approximately the amount of mercury released into the environment (Gunson *et al*., 2006) in Ghana no such dependable data to access the extent of Hg contamination had been documented according to Donkor *et al*. (2006) so how much mercury is being released into the environment is unknown. Also diesel, lubricants of any kind draining from equipments in used at semi-mechanized and mechanized operations into rivers and streams can cause de-oxygenation of water (Ayree *et al*., 2003), hence threatening aquatic lives existing in these water bodies.

CONCLUSION

The ASGM activities are harmful to the physical and social environment in the communities where they operate. Prominent among these harmful activities are direct dumping of waste rocks/tailings and effluents into rivers, river siltation, change of water chemistry, mercury pollution, river damage in especially alluvial areas and improper closure. However, a few of the ASGM operators are undertaking steps to alleviate the impact of their operations on the environment in the communities they operate. Such attempts though commendable must be done properly and must meet the requirements of legislations.

RECOMMENDATIONS

Studies must be conducted in ASGM areas to quantify approximately the amount of mercury released into the environment in Ghana. To contain waste the large volumes rocks/tailings, waste rocks hybrid waste arrangement (Porgera Joint Venture, 2009) where competent rocks are stacked in stable dump configuration and incompetent rock placed in small valleys near the sites is proposed as this approach will eliminate catastrophic failures. This arrangement will create every high mine-derived, suspended-sediment concentrations immediately downstream of the mine rather than spreading the waste far and wide. The Environment Section of the various District Assemblies where these small mines operate must institute downstream water monitoring of mercury, heavy metals, other chemical and biological indicators related to health. Intensive mitigating mercury risks need to begin with efforts at improving awareness of ASGM operators to the dangers of mercury to their health and the ecosystem. All defaulting ASGM operators must be dealt with rigorously according to the laws legislated for such offence.

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