



MINIMIZING LOSSES, SOCIO-ENVIRONMENTAL PROBLEMS AND OPERATIONAL DIFFICULTIES IN THE ACTIVITIES OF ARTISANAL AND SMALL-SCALE GOLD MINING IN NIGERIA

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Abstract

Artisanal and small-scale mining (ASM) is laden with problems of all sort. Low recovery, social and environmental issues, operational difficulties, use of crude mining and processing techniques, lack of equipment and little contribution to the GDP are some of the common problems; yet ASM accounts for over 75% of all mining businesses in Nigeria. Detailed field investigations and laboratory tests were carried out to understand the modes of operation in Artisanal and Small-scale Gold Mining (ASGM); the exploration techniques, mining methods used, techniques used for gold processing and extraction, wastes and tailings disposals and compliance with existing national regulations. It was found that ASM activities create unsightly scenes with abandoned excavated places, littering the environment with pits, stagnated ponds, surface undulations, polluted water and soil bodies and barren surface portions which usually kickstarts gradual climate change. The survey of ASGM activities also showed that in addition to losing up to 60% of the in-situ gold, the same environmental and social problems were common to all the mining sites visited. These problems are attributed to limited knowledge of mining, processing and waste/tailings disposal methods by the operators. Unaffordable cost of excavation equipment, absence of definite regulatory law on artisanal mining methods and non-enforcement of the existing mining laws among others are other causes observed. Proposed solutions include recommendation of a modified form of open cast mining method with continuous environmental monitoring and remediation. It is also recommended that underground and underwater mining by artisanal methods should be prohibited entirely.

Keywords: *modified open cast mining, random site working, value loss, barren surface portions, artisanal underground and underwater mining.*

Introduction

Weighing the actual benefits against the problems created, artisanal and small-scale mining (ASM) as being practiced presently in some parts of Nigeria and elsewhere around the world is obviously a menace; especially when one considers the environmental problems it creates, the loss of values incurred due to use of poor, undefined mining methods and inefficient processing techniques, and the almost total loss of order with its associated social issues. The activities of artisanal and small-scale miners (ASM) cover all areas of the minerals industry in Nigeria including

quarrying, industrial minerals mining and processing and even the new trend in local refining of crude oil which I will describe as artisanal crude oil refining (ACOF). These problems are however, more pronounced with artisanal and small-scale gold and gemstone mining (ASGM) than others because ASGM is wide spread than the others in Nigeria. In fact, ASGM is a global practice (Muhammad *et al.*, 2017).

ASGM employs very crude methods for mining and processing leading to significant loss of value in most of their operations. As a result, even old mine sites and

waste dumps still yielded some values when reworked. For some reasons AGSM cannot be completely eradicated regardless of whatever efforts the government make to stop this informal mineral sector. For one reason, it is a traditional method of mining which provides employment opportunity for a very large population especially in rural communities. Although a worldwide practice, ASM is particularly widespread in developing countries in Africa, Asia, Oceania, and Central and South America (Mallo, 2012). Amadi *et al.* (2018) showed that an estimated 20 million people from over 50 developing countries were directly engaged in the ASM sector as at late 2017. Seccatore *et al.* (2014) estimated over 26 million people including women and children from those 50 developing countries most predominantly in Africa and South America. It is also estimated that more than 70% of all mining and mineral businesses in these developing countries are artisanal and small-scale. This explains why ASM creates major problems because it is practiced by individuals, groups, families or cooperatives with little or no expertise and technical know-how to exploit the minerals.

In Nigeria, ASM especially artisanal and small-scale gold mining (ASGM) have prevailed since around 1902 and the practices have always been unguided and unregulated. More than 95% of mining activities in Nigeria are artisanal and illegal, and they contribute largely to environmental degradation, and poor-quality operational techniques and losses in revenue to the country by way of exports (Mallo, 2012; Ajaka and Onyemaobi, 2014). Thus, although recognized, ASM and ASGM are usually not supported by governments and environmentalists, because of its potential for environmental damage, social disruption and conflicts. Health issues are also associated especially with artisanal and small-scale gold mining (ASGM) because of the use of gravity concentration methods such as panning and sluicing during the processing phase which encourage dumping tailings with dispersed active heavy metals indiscriminately; the same as their mining methods excavates haphazardly and disposes waste disorderly (Lisa, 2014; Muhammad *et al.*, 2017). Oladipo *et al.* (2014) carried out a neurological and assessments of the hazards due to contamination from gold mining in Bukuyum Local Government area of Zanfara State, Nigeria and found that the concentration of heavy metals like Co, Cd, Zn, Cu, Ni, Pb, Mn, Fe, and Cr in the water types (Boreholes, Wells, and River) were above the limit approved by the Nigeria Federal Environmental Protection Agency (FEPA).

All artisanal gold miners follow some major steps and procedures in recovering gold from their ores. The procedure followed depends on the type of ore and local practice. The major steps are excavation (mining), gold recovery (processing and extraction) and sale. But most of these activities of the ASM create

social problems in the form of conflicts with host communities on issues including destruction of farmland and local occupations in addition to other serious environmental problems (Plate 1). Some of these problems are impossible to eradicate though can be minimized. It is now understood that the more government tries to enforce the law to minimize the impacts, the more resistant the artisanal mining operators become. Formally recognizing them as a major but informal component of the mineral sector has not made them improve their methods of operation or solved the huge environmental problems deliberately created by the use of those methods. It has been reported in local media in Nigeria that the seemingly invincible insurgency and banditry in some parts of the country are linked to the continued activities of illegal mining of precious and strategic minerals using artisanal and small-scale mining (ASM). The new trend in this sector is the general awareness of the importance of lithium whose minerals are said to be abundant in Nigeria (Amadi *et al.*, 2018; Haruna *et al.*, 2020); and many ASMs are trying to understand lithium ores and are now searching for them as much as they search for gold (Muhammad *et al.*, 2017).

A review of the problems associated ASM prior to undertaking this research revealed that the problems are mainly due to the ASM methods of operation especially the absence of an approved or good mining technique, a lack of technical competence in mining and the unavailability of appropriate equipment for excavation, processing and extraction. This article is an extract from a study conducted on artisanal and small-scale mining and processing of gold; and the aim was to proffer solutions to some associated problems including the development of a complete set of equipment for processing and extraction of gold that is adaptable to the activities of ASGM.



Plate 1: An Artisanal Mining Site Showing Destruction of Farmland with Other Environmental Issues

Gold Ores Mined by ASM

The ore types usually worked by artisanal and small-scale miners are alluvial or placer deposits, and sometimes, rock-embedded gold ores. The alluvial materials may be loose sandy or clayey alluvium usually found in secondary sedimentary formations or in completely weathered host rock formation that has released most of its metal values into primary sediments so, their metal values are still in-situ (Getso *et al.*, 2014; Amadi *et al.*, 2018). The gold values in most of the alluvial materials are free small-grained gold of size about 2 mm and below, though nuggets measuring up to 10 mm and above are sometimes found. Values in primary and secondary formations may also be embedded in quartz and gravels that must be crushed and grind to free them before extraction (Getso *et al.*, 2014; Haruna *et al.*, 2020). In that case, it is crushed by hand to gravel size using hammers or a site crusher if available, then ground with mills (which is usually installed if a crusher is on site) and finally processed for

extraction by amalgamation (Ajaka and Onyemaobi, 2014; Getso *et al.*, 2014; Muhammad *et al.*, 2017).

Embedded gold ores are found in various types of host rocks which may be basement including some sulphides ores (arsenic, iron, copper), silver-rich ores, oxides, and quartz-vein lodes. They can also be sedimentary in shales and sandstone formations. This implies that gold ores are generally polysulfide, gold-quartz, gold-tellurides, gold-antimony but tellurides and sulphide ores are most common (Getso *et al.*, 2014; Muhammad *et al.*, 2017). Generally, placer golds are the favourites of the ASGM. Some of the samples shown in Plate 2 are not commonly found in alluvial deposits. Gold inclusion in some host rocks is not as visible as shown in the figures but rather finely disseminated as if in solid solution in the rock mass. The artisanal miners usually search for alluvial formations around existing river sides, on accreted river beds and banks and weathered hill and mountain sides (Ako *et al.*, 2014; Haruna *et al.*, 2020). Most of their sites are in sedimentary formations.



Plate 2: Some Rock Samples with Gold Stains or Embedment (ftmmachinery.com)

Usually, a small amount of gold is extracted from large volumes and areas of excavated land which results in piles of toxic tailings and wastes that contain heavy metals and other toxins. These are absorbed into the soil, thereby creating high levels of soil contamination which make the soil harmful to plants, animals and even humans. Air pollution is created from various processes associated with ASGM. Additionally, exposed land surfaces raise large amount of dust which also contain harmful substances and when rain washes this dust overland and into the streams, more problems in the form of acid drainage and vegetation loss are created (Kaufman, 2016; Muhammad *et al.*, 2013). The land is equally degraded by the presence of heavy metals in soils. Although some of these metals are essential to plants, animals and human well-beings, only small amounts are required and in forms that plants can safely assimilate; but ASM activities generate higher amounts that make the environment toxic in the presence of these high metal concentration (Getso *et al.*, 2014; Muhammad *et al.*, 2017).

Processes of Gold Recovery

Although the mineralogy of an ore determines the best recovery and extraction process usually employed, most of the available commercially viable gold recovery processes follow some stages of operation after mining. Depending on the type, the ore may first be concentrated by gravity separation such as the use of sluice boxes, rocker boxes, jigs, spirals, shaking tables, centrifugal concentrators, even dry washers (Lehne, 2016; Muhammad *et al.*, 2017; Wang *et al.*, 2020) and the concentrate treated for gold extraction by processes like amalgamation with mercury, or directly by pyrometallurgy. The ore may also be concentrated by flotation and gold extracted by mercury extraction. Leaching with lixivants such as acids, alkalis, cyanides, and several other chemicals is also used with cyanide leaching as the most widely used commercial method for gold recovery from its ores (Lehne, 2016; Wang *et al.*, 2020) Various methods of leaching are also available including agitated tank leaching, heap leaching, dump leaching, leaching as well as in-situ leaching techniques. Gold recovery from the pregnant

leach solution is accomplished by precipitation, electrowinning, solvent extraction, carbon adsorption techniques including carbon- in-leach; carbon-in-pulp or carbon-in-circuit and other extraction methods. Recovering gold from refractory ores can take additional intermediate and primary processes such as autoclaving (pressure oxidation), pre-oxidation, caustic or lime pretreatment, roasting, chlorination.

Gravity concentration processes rely on the principle that gold has higher specific gravity (density) than most of the host rocks minerals that are associated with the ore. Elemental gold has a specific gravity of 19.3, and a typical gold ore has a specific gravity of about 2.6. Having been prepared through comminution and particle shorting, all gravity concentration devices create relative movement between the gold particles and host rock mineral particles in fluidized media. The density difference then helps to separate the heavy species from the lighter species of material, thus concentrating the gold grains for extraction by other applicable techniques. In addition to specific gravity differences, the effectiveness or performance of gravity concentration is also affected by particle size. Thus, if the ore is classified after liberation, it becomes more efficient to treat feed of the same particle range.

Refractory ore processing methods almost always serve only one purpose, to treat ores that will not liberate their values by physical separation or conventional cyanide leaching. The refractory ore treatment process is then followed by a conventional cyanidation step.

Amalgamation is one of the oldest processes available for gold extraction. It relies upon the contact of ore with mercury to form a gold-mercury amalgam. This process is strongly out of favor with the major mining companies, due to the extremely toxic nature of mercury and the process' inferior performance when

compared to the available alternatives, especially if the ore is refractory. The process is still used extensively by artisanal mines in third world countries and in some small-scale mines due to its simplicity.

The flotation process employs surface properties of mineral particles and pulp conditioning to produce a concentrate of gold minerals from an ore using certain chemical agents, mechanical agitation and air inundation of the pulp containing the ore. Specific chemicals perform functions such as activation, depression of mineral species, conditioning of pulp and foaming. The flotation process is effective only if the gold particles are well liberated from the gangue minerals.

Methods

Field works were carried out in a number of places where artisanal gold mining activities are known to be prevalent in western Nigeria and some parts of the north central states of Kogi, Niger; and Kebbi in the Northwest. Figure 1 shows the states in Nigeria covered by the field activities. They included parts of Osun, Oyo, Ekiti and Ondo state in western Nigeria where artisanal gold mining, gem stone search and mining, sand mining, and rock (granite and limestone) quarrying and processing at the ASM levels are common. Although small-scale mining and processing of industrial minerals such as calcite, dolomite, gypsum and others are the common activities in north western part of Edo State covered by our survey, a few artisanal gold mining and extraction are also identified in the state. The locations covered in Niger State were limited to Shiroro and environs where artisanal gold mining is predominant. Although it is known that artisanal gold mining and processing are rampant in some of the northern states like Sokoto, Kebbi, Zamfara, Katsina, Nassarawa and others, our field surveys were limited to parts of the states indicated in Figure 1.

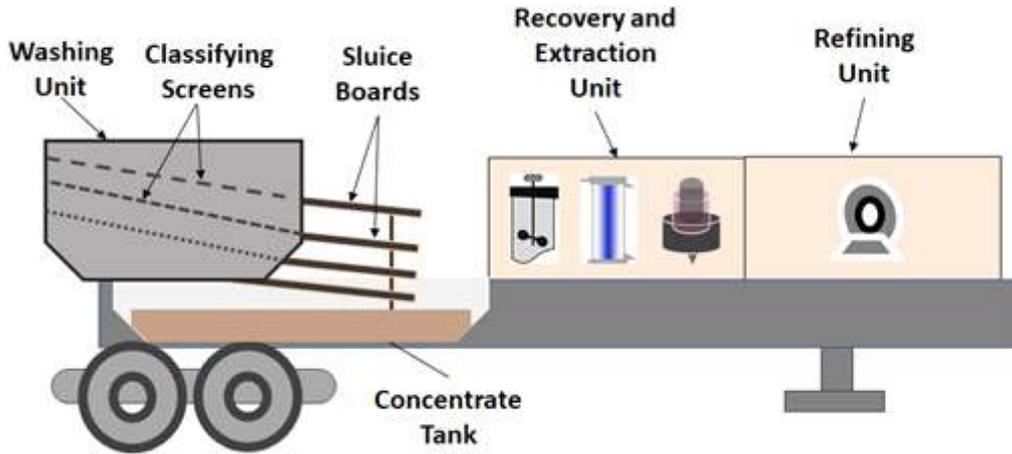


Figure 2: Sketch of a through the Equipment Trailer

Results and Discussion

Compositional Analysis

Results of compositional and petrographic analyses for some of the rock samples are presented in Figures 3. Some results indicate the presence of gold in the samples. The summary of the XRF results for samples collected from some locations in Kebi state, shown in

Table 1 for example indicate the presence of gold and elements such as Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Ag, Rb, Zr, Nb, Mo, Cd, Sn, Sb, in addition to the major ones in the table. The XRF machine did not indicate the presence of oxygen in the samples and the sulphur content is low, not significant enough to conclude that the ore is of sulphide origin but may likely be complex or refractory.

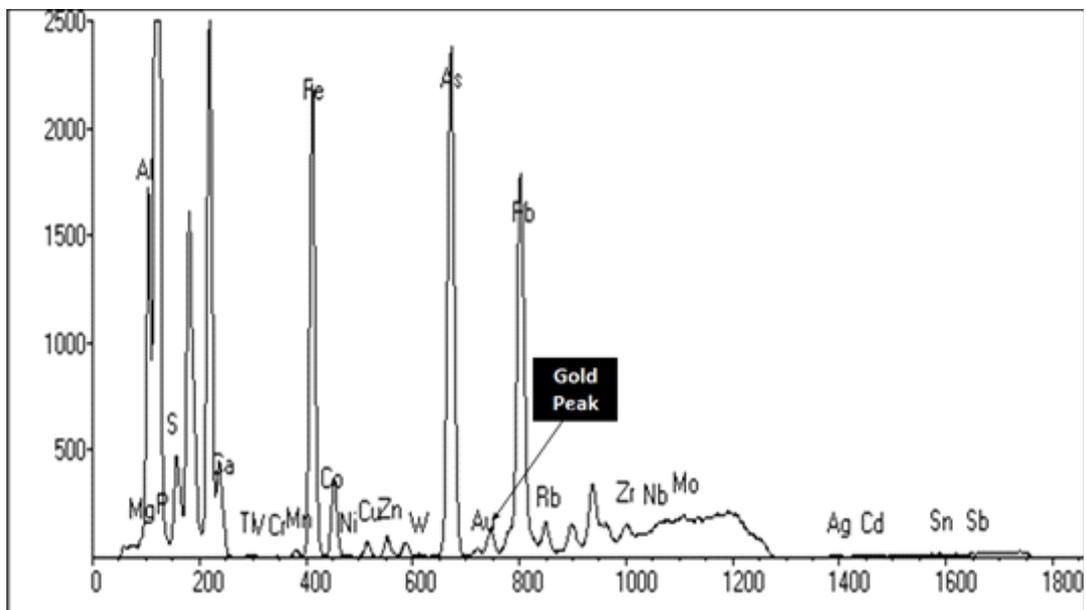


Figure 3: XRF Intensity Curve for a Site in Kebi State

Table 1: Summary of Results of Compositional Analysis by XRF

Element	% Au Content		
	KEBI I	KEBI II	KEBI III (Downhole)
Al	6.6101	8.7908	9.4059
Si	39.7716	40.9775	31.7950
P	0.1825	0.2012	0.2066
S	0.8353	1.2294	1.6168
K	4.4089	5.0457	4.9334
Fe	4.3669	9.2032	6.7657
Pb	2.2093	1.4983	4.8081
W	0.0585	0.1456	0.0673
Au	0.7484	1.2205	2.0494

Results of petrographic analysis by thin sectioning and photomicrographic examination shows that quartz and aluminum are the most abundant elements in the samples. The photomicrographs also indicate the presence of other metals resulting from association with quartz (Figure 4) which may indicate that the gold in the ore is not free grained.

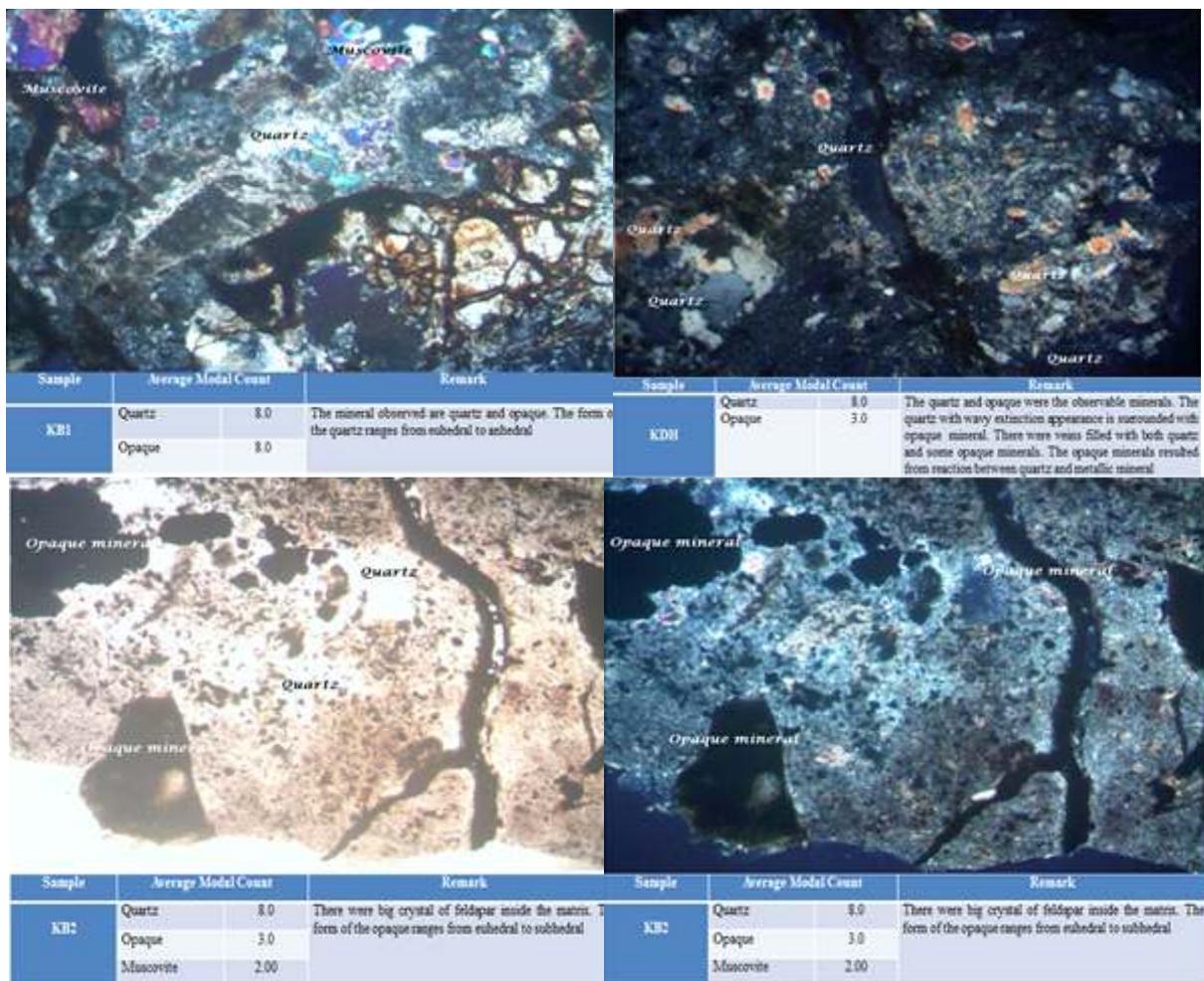


Figure 4: Photomicrographs of Thin Sections for Some of the Samples

The full results for all the samples, their detailed analysis and implications for gold extraction are presented with results of gold recovery tests for performance evaluation of the processing equipment developed.

Mining Methods

It was observed that the mining methods used are the same in all the states and sites visited with minor differences based on the scale of operation or whether the formation is consolidated or loose alluvium. The mining technique used in all the sites was surface excavation except in Shiroro area of Niger State where the miners followed a band of shale materials embedded with fine gold grains into a shallow underground network through a poorly constructed adit. The underground work was observed to be subject to seasonal operations as it was workable only during dry season due to flooding.

Generally, the surface mining technique used by these miners is localized pitting using diggers, shovel, pans and a small mobile pumping machine to create shallow circular pit across a depth of 2 to 4 stratigraphic layers of materials to get to the layer or sediment which usually hosts the gold. The gold-bearing sediment shown in Figure 5 is usually very thin compared to other layer; sometimes about a meter thick or less and is thought to have been deposited by stream action on river bank or bed as the river changes its course over time.

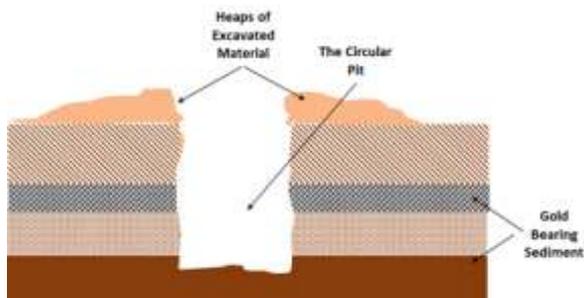


Figure 5: Typical Vertical Cross-Sectional View of the ASGM Pit

In some locations, the gold-bearing layer is encountered at 2 stratigraphic levels in the same pit as shown in Figure 6. On finding the gold bearing sediment, the miners begin to create several pits all over the area to intercept the sediment and winning only the little value the limited volume of material mined within the pit rather than create an opening or trench of sufficient width and excavate the sediment in a particular direction to mine more of the sediment for processing so as to maximize recovery. Thus, the selection of a location for excavation is random, the same as the subsequent excavation by pitting. The first pit dug in an area appears to be the exploratory pit and it determines the direction of subsequent activities of the

Artisan miners in that site. If the pit wins, (that is if it intercepts a productive sediment), other pits are created all over the area, but if a barren sediment is encountered, another trial pit may be created, otherwise the area is abandoned.

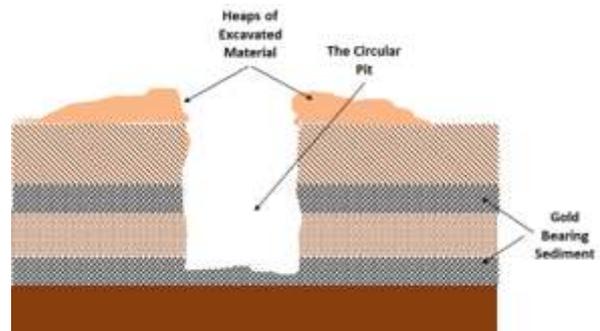


Figure 6: Gold Bearing Sediment Intercepted at Two Levels

One major disadvantage of this pitting method of mining is that the miners leave much of the gold-bearing sediment unmined thus, loosing that much gold value in the area also. This method also leaves the entire area littered with pits, surface undulations, crisis-crossing downed trees, open plain surfaces susceptible to erosion and loss of portions or an entire land use area (Plate 3).



Plate 3: A Typical Cash-Crop Farm Cleared for Artisanal Mining

As a result of their mode of operation, it is also very difficult to estimate the gold production by ASM since there are no reliable way of collecting data on their production because the miners will not willingly disclose their recoveries. This problem was also reported by Seccatore *et al.* (2014); Amadi *et al.* (2018) and NEITI (2023).

In the course of conducting this research, it was discovered that artisanal gold miners can belong to two categories based on their work practices. The small-

scale gold miners work much the same way as the traditional artisanal miners, but this group (small-scale) use locally fabricated or imported mobile washing machines (Plate 4) and are sometimes able to rent excavators to mine the ore for some days and create stock piles which they process by gravity washing for days or even weeks before the excavator returns again and make another ore pile. This category of small-scale miners also operates at different levels. There are those who permanently employ excavator and dozer with a little more sophisticated and higher capacity mobile washing equipment. Majority of the operators in this category are Chinese nationals. Though working also

with some influential people in the communities, they use hired security men (usually members of the Nigeria Mobile Police Force) or some private security company to prevent entry to their work area. No picture of the machines and site are allowed to be taken. We understand based on our analysis that while this is done with the pretense of protection or security, the main reason is to prevent people from understanding how the wash plant works, thus making it difficult to be produced by local fabricators. Notwithstanding the different levels or scales of operation, the artisanal miners employ the same methods for excavation, processing and leave the environment devastated and unsightly.



Plate 4: Small-Scale ASGM Using Locally Fabricated Washing Equipment (a) Without Excavator on Site and (b) With

The environmental problems generated are even more significant with small-scale mining group than the traditional artisanal miners based on their capacities of operation. Some artisanal miners are indigenes of the states and communities where they practice but they follow the same method as the migrant miners so that their mode of operation is the same. It was also discovered that most of the migrant miners work for some local influential people and they share the recovered gold value according to a pre-agreed ratio. This influence of local artisans is one big factor that is responsible for almost total lack of care for the environment and local occupation. Our findings also revealed that most of the artisanal mining sites are in an existing farmland and other active local land use occupations. Most of the sites in the west, for example

are found in cocoa, palm, rubber plantation and other cash crop farms including fishing areas.

Gold Processing and Extraction

Processing of the gold-bearing materials also follow the same procedures which include removal of the lumps of gravel and washing to concentrate the heavy black sand component containing the gold, followed by gold extraction using amalgamation and smelting. Removal of the lumps of quartz/gravel is done manually with hands by the traditional artisanal miners but some of the small-scale miners have coarse screen installed on their mobile washing unit to help remove lumps greater than 50 mm in size. The screen underflow is then washed through a single stage sluice board with trapping mat to attract the gold grains.

The sluice board is slightly different in size for the traditional manual miners from the small-scale miners who operate much longer sluice board with trapping mats. The traditional artisanal miners also use panning method to concentrate gold and associated black sand materials in the ore. The concentrated gold particles are then extracted by amalgamation with mercury. The mercury is then evaporated leaving the gold grains behind. There were also smelters who come to site with a mini gas-fired furnace and get paid for helping the miners fuse the gold grains into a single lump. These practices make the traditional artisanal miners get far less returns on their hard-won gold apart from leaving much value unmined.

The marketing method for the gold is also different from the traditional and small-scale mining groups. Some of the small-scale miners have markets for their gold outside the mining site. The Chinese in particular appears not to even process their material beyond washing but export it as-washed. But most of the traditional artisanal miners sell their value to an on-site buyer who visits the site daily and buy the gold. Some arrangements also involve the community partners in the marketing of the gold where an intermediary stand in between the miners and the community persons concerned. The gold is either sold and the proceed shared according to an arrangement or the miners are paid off their due.

Social and Environmental Problems

The identified socio-environmental problems cut across all stages of operation of these artisanal mining groups. The prospecting method is very crude and mainly involved accessing an area suspected to have gold bearing sediment base on intuition and previous knowledge of the place; A pit is then dug while visually analyzing every stratigraphic material until the layer suspected to be gold bearing (if present) is reached. If no sediment bearing gold is found, the pit is abandoned and another one dug; several of such pits may be dug and abandoned thus, constituting trap for small wild animals.

As observed, most of the traditional artisanal miners are migrant workers who move between the states where artisanal mining takes place according to some work seasons. Findings show that majority of these workers, including some foreigners are very promiscuous sexually and so are known to carry some sexually transmitted diseases (STDs) around. It was also confirmed that many of them use and sell hard drugs and are known to influence young people even those of college ages in those places to take drugs. These are social problems that are difficult to thoroughly investigate and eradicate as long as artisanal mining operations continues as being practiced presently.

The mining and processing methods employed by the artisanal and small-scale miners eventually result in

generation of large volume of waste and tailings which constitute a huge environmental problem that the miners in all places visited never attempted to solve or even minimize. Once they are no longer able to dig to winning depth, they abandoned the location for another. The result is that apart from the large volume of waste generated, the entire surface area is littered with pits, un-vegetated land portions and surface undulation that make it difficult for other activities like farming to be undertaken in the place. The effect of this therefore is that in addition to losing part of the farmland which have been cleared for mining, the capacity for local occupation is also largely reduced (Plates 3). This sometimes results in serious conflicts within most of the mining communities. It is observed that the surface undulation and scattered mined pit problems would have been minimized if a move systematic mining and waste/tailing disposal methods were adopted. These problems exist, also because no attempt has been made to develop a particular mining method for use by the ASMs.

At some of the sites visited, the pits were significantly narrower compared to their depths, thus making the possibility of failure by caving or wall collapse very high, especially after a raining period. The mine pits and process ponds were also left with stagnated water some of which appear obviously contaminated and polluted. It was equally observed that the problems were made serious due to the collaboration between the miners and those promoting or sponsoring them in the communities which makes the enforcement of existing regulations ineffective even by the Federal Mines Officers (FMOs).

To minimize the problems, it was proposed that a modified form of open cast mining method with specific working geometry (dimensions) should be developed and enforced for use by ASMs regardless of their status. The enforcement should be handled by the FMO in each state possibly working with Mine Police or other security agent as the traditional artisanal miners could become violent sometime. This proposal recommends that ASM should not be allowed to mine ores or minerals at certain depth below the general surface datum in an area. Eight meters (8 m) is recommended if excavation is manual as with traditional artisanal miners and twelve meters (12 m) if excavator is to be used. The width of opening ($m = 2y+x$) in Figure 7 should not be less than 200% of the width of mineralized bed (x) to stripped per opening, and about 25 m of stripping length (L_m) as minimum working unit as shown in Figures (7-8).

Excavation should proceed along mineralized line in either direction. A group of miners can also come together to acquire or lease mining equipment – excavator, dozer and loader. If the deposit is not vein formation or a stream bed deposit but lithologically expansive, the method can still be applied by stripping.

This recommendation implies that site for ASM operation should always be approved before commencement of operation and mineralized bed below 15 m from the surface should not be approved for mining by artisanal methods. This recommendation also implies that underground mining by artisanal methods should be discouraged entirely and not

approved. If the deposit is rich and economical in size, a well-planned and designed mining technique should be used and then a number of artisanal mining groups can come together to execute the project. This is just a recommendation and not a standard because the dimension may vary according to the judgment of the FMOs.

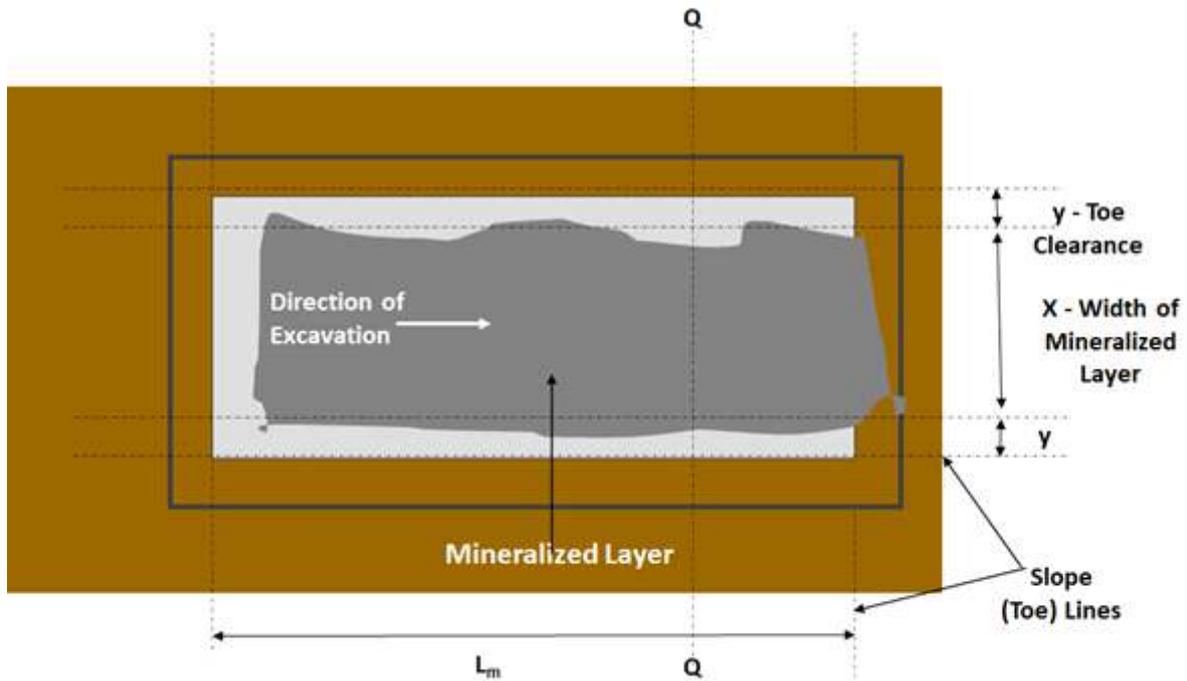


Fig 7: Plan View of the Recommended Mining Method

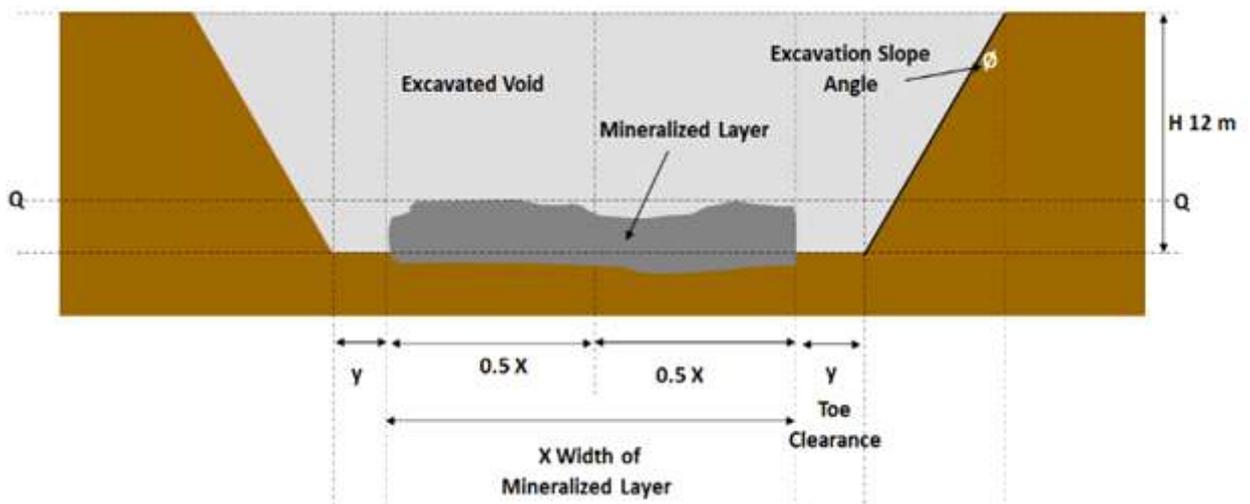


Fig 7: Plan View of the Recommended Mining Method

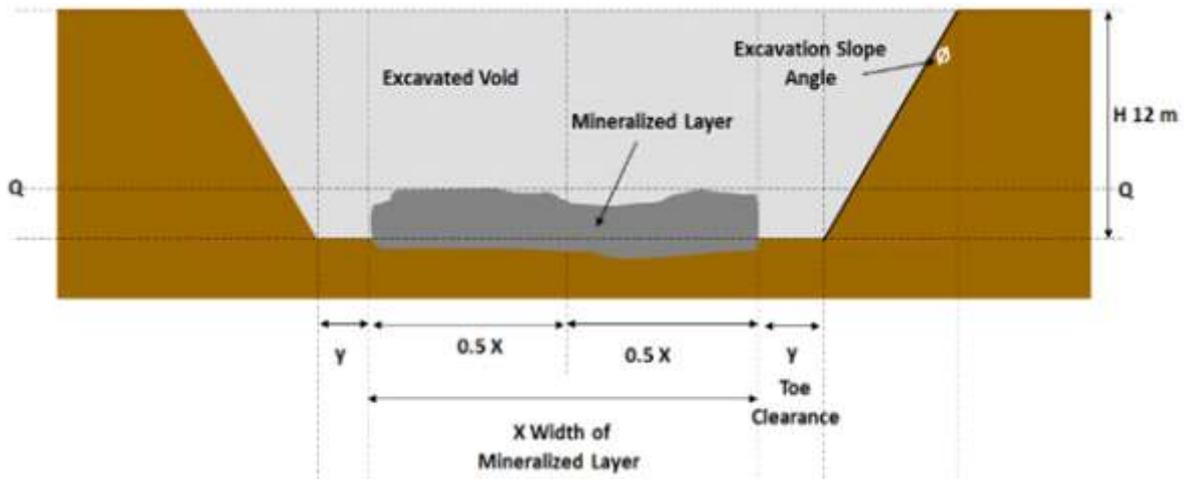


Figure 8: View Across Section Q-Q of the Recommended Mining Method

There is also what was sometimes described as LOTO mines in which artisanal miners excavate narrow holes to access and follow shallow underground mineral vein. In most cases, both the hole (shaft) and the drift are not well supported and this has resulted in many fatal accidents (Mallo, 2012). Local mining activities have also been carried out under water. Though not common in Nigeria except few individuals who still mine sand underwater in Lagos area and some riverine communities for sale to construction workers using buckets and wooding boats or canoes. The small-scale miners (sand dredgers) in this category use imported or locally fabricated dredging equipment of various type to excavate the sand into barges and do not have to go underwater. These forms of mining activities (underground and underwater) should not be approved for artisanal miners with the exception of the small-scale operators in this category. Approval for artisanal mining should therefore be limited to land surface only. Part of the proposed recommendation to minimize the environmental problems associated with the ASM operation is tailings and waste reuse. The tailings are usually finer material than the waste and can thus be easily converted to construction materials especially building bricks for use in local communities. Brick making machine may be fabricated locally for this purpose. If mine wastes are from alluvia deposit, these may also be used with the tailings after sorting. The coarse waste can also be crushed and used as above otherwise it should be used for stabilization of local roads and land filling for erosion prevention. The waste and tailings may also be used to fill or reclaim the mine pits for re-vegetation where possible. Where stagnated ponds still exist after filling for reclamation, it is recommended that these be excavated or dredged, treated and prepared for other land use possibilities such as fishing and for recreation.

The most critical problems with mining and processing of materials are the health or well-being and safety of workers and the effect of their operations on the

environment. But these problems are more serious with the unorganized artisanal mining and processing of minerals especially those of gold since they generate larger quantities of wastes and tailings to win very small amount concentrate from which they extract their gold. There is the danger of ingesting carcinogenic dust during mining and processing, heavy metal contamination of water, soil, vegetation and the environment generally. There is also the danger of slope face failure, wall collapse, mud slide, rock fall, surface caving, flooding to mention a few. Artisanal miners usually fall victims of these incidences fatally because they are not organized and not equipped to handle them. Some do not even know that these problems exist until one occurs.

It is also recommended that the Mines Office in areas where the ASM activities are prevalent should organize a system of periodic lecture to educate artisanal miners and processors on safety and health issues in mining and minerals handling. Ensure that the operators undertake periodic medical check for their miners and processors, and prohibit pregnant women from working at an artisanal mining site. The operators can also be organized to receive assistance on equipment hiring or leasing and profitable marketing of their products. They may also be organized into cooperative system where individuals or groups can draw fund at minimal rate to finance improvement in their jobs and train members in the required skills for maximum yield while allowing the law to guide their operation.

Conclusion

Although ASGM accounts for over 75% of mining businesses in Nigeria, but as being practiced presently in country, it has no specific mining method, specialized equipment and regulatory approval for its operations. Excavation is haphazard and gold processing and extraction are crude resulting in significant revenue losses due to low recovery with an

avalanche of environmental and social problems which presently make ASGM a menace. However, with the adoption of a mining method specifically designed for its operations and the use of appropriate equipment with adequate monitoring for environmental and legislative compliance, ASGM is a potential source of revenue, job creation and economic diversification for industrialization in Nigeria.

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