Scouring abandoned mines in search for elusive metal (gold) in Kakamega’s Rosterman area - A case study in Kenya

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Abstract—Artisanal and small scale gold mining (AGSM) is an economic activity carried out by thousands of people across the globe. In Kenya these activities are concentrated in the Western and Northern regions. One of these areas is the Kakamega County in specific the Rosterman area. The name originates from a British gold mining company, Rosterman Gold Mines which was licensed to mine gold in 1930s before Kenyans independence. Since the exit of the company operations in 1952, small scale miners have been mining on the tailings of the abandoned mines to date. The activity is mostly poverty-driven and the small scale miners face a myriad of problems including rudimentary mining methods, poor processing practices and exploitation by brokers. The mining activities pose negative impacts to the environment and human health. This paper highlights the challenges and gives some achievable solutions to improve the mining activity as well as the living standard of the locals.

Key words: AGSM, Comminution, Mercury, Gold resource centre

I. INTRODUCTION

Gold is a rare element. The average concentration of gold in the earth’s crust is 0.004g/tone (0.004 grams of gold in one tone of rock) [1]. A gold deposit becomes interesting for economic exploitation with grades usually above 0.2g/tone. A rich gold deposit has gold grades above 10 g/tone. The extraction of gold does not depend only on the gold grade but also the mineralogy of the gold (i.e. how the gold occurs in the ore, as well as the accessibility and infrastructure of the site).

Mankind has been extracting gold from hard rock and alluvial deposits for more than three thousand years. Impure gold, as it commonly occurs in deposits, has a density of 16 to 18, whereas the associated waste rock (gangue) has a density of about 2.5 [2]. The difference in density enables gold to be concentrated by gravity and permits the separation of gold from clay, silt, sand, and gravel by various agitating and collecting devices such as the gold pan, rocker, and sluice box.

Unaffected by air, moisture, heat or cold, this noble metal does not tarnish, rust or corrode. It is the most malleable and ductile of metals. Its rating is 2.5 ÷ 3 on Moh’s scale of hardness. It has a specific gravity of 19.3in its pure form compared to 14.0 for mercury and 11.3 for lead.

Gold is used globally as a monetary equivalent in different currencies for prospective purposes. It also finds application in jewelry and allied wares, electrical-electronic applications. It is also used in medical fields such as dentistry, and in the ancient times it was used for healing therapy when worn as bracelet. It is also used in the aircraft-aerospace industry, the arts, décor (as in Buddhist temples in the east) and chemical fields.

In Kenya, gold is known to occur in gold bearing greenstone rocks of Nyanzian Craton in Western Kenya [3]. Areas with alluvial gold are being harvested by local miners through conventional panning in the northern part of the country. The counties with gold deposits are: Kakamega, Migori, Transmara, Bondo, Siaya, Pokot and minor indications in Nandi area. Gold panning in Turkana was first reported in 2005 as occurring at Lochoremoit, Namoruputh, Lokiriama and Ngakoriyiek [4]. In these counties artisanal and small scale mining (AGSM) activities exists as a major economic activity and in many cases as a major source of livelihood [5].

This paper explores AGSM in Kakamega’s Rosterman area, outlining the activities carried out, the challenges faced and finally proposes recommendations addressing these challenges. These challenges are not unique to the location but are similar to those faced by AGSM in other areas. The recommendations are obtained from past research and customized to suit the particular setting. They are also in line with proposed government policies of the National Economic and Mineral Policy.

A. History Rosterman Area

Kakamega County, (0.2833° N, 34.7500° E) in western Kenya Gold mining in Kakamega District was started by a British company by the name Rosterman Gold Mines, incorporated and licensed in early 1930s to prospect and mine gold ores. Since the exit of the British company, the interest in exploring gold deposits was left to area residents and other small-scale miners. The villagers have for years been scouring the abandoned mines in search of this elusive mineral to date.
B. Mining methods

The artisanal and small-scale miners process two major categories of gold ores: alluvial and hard rocks. The mining in this area can be categorized into alluvial mining and hard rock mining. Alluvial mining involves digging ore from the slow moving sections of river Isiukhu. The gravels of the ore excavated from these river and tailings on site are usually carried to suitable locations for processing either by sluicing or panning. In some places, work is organized in family groups with the men digging the ore and the women doing the sluicing and panning, while in others areas, women only carry the ore from the pits to the processing site.

The hard rock, which may be lode or reefs, could be free milling or refractory ores. Hard rock mining is an underground operation which features in open pits with the overburden removed manually by the miners. Others methods feature narrow, vertical/inclined shafts or adits for access to the ore body. The miners deploy a variety of tools (shovels, picks, hammers, axes, chisels, metal bars, mattocks, among others.) to loosen and excavate the ore, especially when in the form of weathered quartzite veins. The ore is then shoveled into sacks and buckets and transported to the shaft.

C. Ore Processing

After mining, the ore is processed to liberate or separate gold grains. In the case of alluvial ores, liberation is accomplished by scrubbing and washing, while comminution is used for hard rock. Primary separation is generally conducted in sluice boards and the sluice concentrate is cleaned in pans before amalgamation. The processing sites are separate from the mining areas and at the proximity of sources of water and power. Some sites act as independent central processing centers that provide a service and treat ore from different sites in their vicinity. The ore is either transported using hired trucks or hand carts, and if within a reasonable distance, carried in sacks.

D. Washing and Screening

The main pre-concentration processes performed on alluvial material are washing and screening. Washing is carried out mainly on alluvial gold ores to remove pebbles, break up clay and remove slimes. The extent and mode of washing usually depends on how strongly the clay adheres to the surface of the gold. If the clay content is low and adhesion to the mineral surface is weak, washing and screening are done simultaneously, usually by shaking a hand held screen (with the material in it) in water. Other miners perform this operation by pounding and shearing the material with their feet in basins after pre-soaking with water. The process continues until the gravel and sands are relatively clean. Screens used in gold processing are usually selected on the basis of gold particle size in the area under consideration (with nuggety areas using screens with larger openings). Most small scale miners use metal woven screens for coarse separation and rayon-type material for fine screening.

E. Concentration

Liberation from hard rock ores begins with comminution. Size reduction is done using hammers and ball mills. The big rocks are crushed manually while secondary milling, ball mills acquired mostly from Tanzania are used for grinding the ore into fine particles. In most processing centers, the units may only work for part of the day, unless there is sufficient ore available for continuous operation.

F. Communication

The miners use crude homemade sluices made of wood sluice boxes lined with either a basic blanket, towel, carpet or jute material. Most sluices seen during the survey only had one type of lining that is not applicable to all particle sizes. In most sites visited, the sluiced tailings are scavenged several times before they are finally discarded to increase retrieval of gold particles lost in previous operations. There is a lot of scope for improving the design of the sluice boxes used.

After the first separation operation such as sluicing, concentrates consisting of black sands with a small percentage of gold are produced. These are generally cleaned by hand panning in wooden or rubber pans (cut from rubber sheets). This panning produces a gold-rich concentrate but this still contains a lot of black sand. Separating the gold from this concentrate is easy if the gold is coarse but a major problem when it is very fine grained. In most places, miners use mercury amalgamation to separate the gold from the black sands.

Fig. 1: Sluice used for concentration of gold ore

II. CHALLENGES FACING AGSM

Small-scale mining can be extremely damaging to environmentally with serious health and safety consequences for workers and surrounding communities [6]. AGSM can play a crucial role in poverty alleviation and rural development; most of those involved are poor and mining represents the most promising, if not the only, income generating opportunity available [7]. However, the sector is
perhaps better known for its high environmental costs and poor health and safety record [8].

A. Prospecting and Mining

Exploration is one of the most difficult aspects of mining. ASGM mainly relies on prospecting by trial and error - walking the ground and testing for gold content. In general, there is little regard for proper health and safety procedures, and underground mining in particular is a dangerous and hazardous activity. The miners face daily and immediate danger of rock falls that kill or maim instantly. Technology in mining has increasingly advanced leaving many small scale miners still using rudimentary mining methods partly due to poverty and ignorance. The miners often work as a team using open pit method. The gangue is removed manually to unravel gold veins. The gold is crushed and then carried to a nearby Isiukhu river to pan and separate the gold. This method of mining requires a great amount of labor, and is very slow, time consuming and not very profitable. Working inside these mining pits is the most dangerous method of gold mining with frequent cave-ins and suffocation from carbon monoxide emitted by generators [9]. The miners are exposed to other hazards and uncomfortable conditions on the mine [10]. The act of drilling produces large quantities of dust.

B. Processing

After mining the process of crushing and grinding (comminution) the gold ore follows. The processing method involves grinding, panning in the river and use of mercury to amalgamate gold. The grinding process involves milling machines whose efficiency is not optimized leading to wastage of energy and direct increase in cost. These mills break down and require repairs on a very frequent basis. There are extremely high levels of airborne dust at the centralized processing plants as this grinding is invariably dry. In many cases, the comminution is carried out inside huts or buildings with no proper ventilation to remove the dust. In such places, the workers are exposed to dangerous levels of siliceous dust and high noise levels but are rarely suitable. Personal Protection Equipment (PPE), dust masks or ear plugs. The noise level is very high as shown in Table A1 shows the noise levels in decibels as measured from a ball missing site in Rosterman area. Prolonged exposure to unacceptable noise levels and can lead hearing damage [7].

Panning is a gold processing method which involves separating gold particles from the ore by gravity. The process requires a lot of water and is done on the river which has led to shrinking of the river. Although other activities like deforestation and poor farming methods have contributed to shrinking of the river, the gold processing activities have also added a share to the shrinking of the river.

C. Mercury Use and Environmental Effects

Mercury vapors in the air around amalgam burning sites can be alarmingly high and almost always exceed the WHO limit for public exposure of 1.0 µg/m³ [8]. These exposures affect not only ASGM workers but also those in the communities surrounding the processing centers. The vaporized mercury eventually settles in soil and the sediment of lakes, rivers, bays, and oceans and is transformed by anaerobic organisms into methyl mercury. Mercury exposure in ASGM communities is associated with adverse health effects including kidney dysfunction, autoimmune dysfunction, and neurological symptoms [9]. Mercury that poses long term hazard from a slow cumulative poison may seem a comparatively small risk. Mercury is toxic and inhalation can harm nervous, digestive and immune systems, lungs and kidneys, according to the World Health Organization. Inhaled mercury can be fatal, according to the World Health Organization (WHO).

D. Economics

Many of the potential economic benefits of the small-scale mining sector are lost through poor practice in mining, processing and marketing the target minerals. They then add mercury to the metal and wait for middle-men who come to the site mostly in the evening to buy the commodity. The miners work in groups, and distribute ground ore equally to individuals or smaller groups. The miners market the gold through brokers, who frequent the mining sites in the evening. Exploitation by middlemen and cartels means that the benefits rest buried in pockets of foreigners. However since gold marketing is unregulated, tonnes of gold produced by small-scale miners is said to be smuggled out of the country by dealers who have put out gold smith shops in Kakamega town.

E. Social Problems

The dangers of involving children in gold mining areas are common. Thus they lose school days and in the process damage their health. Welfare officers rely on the goodwill of people to report cases but this doesn’t happen often because parents encourage their children to seek employment at the mines. The children are involved either in actual extraction or in ancillary services such as selling food. Besides working in unhygienic conditions, workers have abandoned social life responsibilities to be at the mines looking for this black gold.

III. PROPOSED IMPROVEMENTS

Engaging all small-scale miners at the exploration stage could support efforts to reduce and eliminate mercury use. Planning how best to extract a deposit will help to maximize the resource, minimize land use, and improve gold production, which in turn will make mercury use more affordable and sustainable. Ore deposit type dictates the type of extraction possible, which in turn dictates how mercury is used (and potentially eliminated). Best practices in one situation cannot necessarily be applied elsewhere. Mercury reduction approaches must fit the ore type and current practices. Mercury is effective in extracting very small gold particles. For an effective and safe process, mercury should be reclaimed instead of vapouring it into air.

Grain size of the gold particles must be investigated and understood so that adequate and efficient liberation of the gold particles is accomplished during milling. Running tests on gold liberation and recovery is important and will reveal how to improve gold recovery. A programme of gold grain size measurement, therefore, can be carried out. Samples of gold
concentrate can be collected from mine sites to establish a baseline of gold grain size data. There was virtually no information available about the grain size of gold ores from the ASM mining region.

Alternative, effective and safer substitutes for mercury in gold processing like the well-known retorts can virtually eliminate the release of mercury from the final stages of gold ore processing but projects to introduce them as a best practice in AGSM areas have met limited success. The borax method has been suggested where borax is used as a flux for smelting gold out of heavy mineral concentrates. The alternative methods encourage reduction of mercury use, re-use of mercury or its elimination.

Mercury pollution problems are generally caused by socio-economic barriers to the adoption of better practices. Periodic trainings should be mounted for the miners, where the miners will be engaged and trained on the mining, processing and safety and environmental protection. However, even with education, environmental-impact arguments are often not enough to convince miners to swap to non-toxic gold extraction methods because these often require financial investments which most small scale miners are not able or willing to make. Hence active research on methods of extraction at low cost can be undertaken.

The comminution process should be improved through development of affordable and efficient machinery for the miners. Control technology should aim at reducing noise to acceptable levels by action on the work environment. The miners should be urged to use masks to avoid inhaling dust and mercury fumes and use plastic gloves when handling mercury.

Most of the minerals, especially non-industrial ones, produced in the country are used locally and/or exported without value being added owing inadequate capacity to do so. A gold resource centre targeting small scale miners can be established in the relevant counties these centers can offer technical support, value addition and act as accumulation centers where miners can have access. These will shorten the marketing chain and increase the benefits to the miners and bring ASM into the formal economy thus representing an excellent method of transferring wealth to rural communities: These methods, which detect and measure the amounts of other elements as well as gold, include atomic absorption spectrometry, neutron activation, and inductively coupled plasma-atomic emission spectrometry. These methods enable rapid and extremely sensitive analyses to be made on large samples.

The gold resource centre should be established with collaboration between county governments and Higher learning institutions. The institution can mount relevant research geared toward practical solutions to problems of AGSM. The proposed research and educational measures should include: training of small-scale mining personnel, planners and consultants in suitable educational facilities, for example in the areas of gold analysis, geology, mineral-deposit, geological mapping and mineral exploration organization and techniques in mining and beneficiation, work safety, marketing and mineral economics. Other areas are mercury usage and effects to the environment, Impacts of mining, mining methods, gold particle size, processing methods, noise and dust control and smelting of gold.

There are other measures which the government has been encouraging like fencing off mining areas, covering tunnels, timbering of tunnels to avoid caving in, digging of breathers for pumping air into the mines to avoid suffocation and use of strong and fastened hand pulleys. In addition the miners have been directed to mine during daytime, anchor generators and draining pipes on the ground surface to avoid accumulation of fumes in the holes, use protective clothing, avoid working under the influence of alcohol and ensure they have a well-equipped first aid kit on site. These efforts have not yielded much success hence the approach in training and awareness must be evaluated to yield measurable success.

IV. CONCLUSION

AGSM miners face challenges running from prospecting, mining processing and marketing with social problems. A holistic approach can be used to solve these challenges. Empowering AGSM with knowledge and protecting them from exploitation will play a major role in empowering the rural population. If the miners are economically stable they will be able to acquire gold mining equipment now available to the formal ASM sector, including sluices and shaking tables, jigs, gold savers and centrifugal concentrators. The challenges facing small scale miners are not unique to the case study.

The proposed Mining bill 2014 policy for to assist the Artisanal and Small-Scale Mining Operations, mainstream and formalize artisanal and small scale mining operations. Small-scale mining operations undertaken by Kenyans offer opportunities to support rural livelihoods and develop entrepreneurship. The government must assist their efforts to operate in an economically and environmentally sustainable manner through enforcement of the new bill once enacted.

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