

Environmental Evaluation of Small Scale Gold Mining in the Bonkani Region in the Upper East Area of Côte d'Ivoire

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Abstract: Artisanal mining is usually done by workers with limited understanding of the long term impacts of their activities on the environment and on their health and with limited capacity to mitigate the risks. The aim of this study was to evaluate the environmental impact of this activity in the Department of Bouna where this activity has gained Importance. This study was done through data collection, interviews of miners, traders, and government services' agents, and on site diagnosis. Six steps were inventoried on the mining sites: site prospection, digging holes, crushing mined ore, grinding of crushed ore, washing the flour after milling, and gold recovery with mercury. Among the activities on mining sites, 24% were found to present potential impact of major importance, 39% have potential impact of medium importance, and 37% have minor potential impacts. The major impacts are those impacting soil, landscape, and vegetation and water resources. These results showed that small scale gold mining significantly impacts the environment. As recommendation, it was proposed site rehabilitation by reforestation, the help of miners to use retors which are mercury traps or eventually mercury-free gold extraction technologies such as chlorination. A simple policy of solid and liquid waste management must be developed by site owners. They must ensure the education of miners and of the population living on mining sites on the importance of using and building effective systems for on-site sanitation. Besides that, programs focusing on HIV/STI prevention, with targeted interventions for high risk women must be implemented under private/public/NGO partnership. Since the resilience of the gold mining activities has proven to be one of the main sources of livelihoods in local communities of the extraction sites, the state should define a consistent policy of artisanal gold mining taking into account the environmental, social and health.

Keywords: Artisanal, Mining, Bouna, Cote d'Ivoire, Environnemental Impact

1. Introduction

Gold mining on a small scale which refers to both to the rudimentary process of ore extraction, is a key livelihood activity employing over 13 million workers and maintaining 80 to 100 000 000 people worldwide. It produces about 350 to 800 tons of gold per year and contributes to about 20-30% of world production.

People who depend on artisanal gold mining are generally

from poor rural areas in developing countries [1]. Some people living in rural areas are dependent on mining as the main source of income or as an essential complement to their meager farm income. In many African countries such as Ghana, Mali and Burkina Faso, gold mining has become important because of the escalation of poverty and the lack of employment opportunities in the formal sector [2].

In Côte d'Ivoire, following the socio-political crises, and the economic difficulties faced by farmers in recent decades,

several gold mining strategies have been implemented by population to address the situation. According to the Ministry of Mines, Côte d'Ivoire abounds over 1,000 artisanal gold mining sites and more than 500,000 people live in this rural activity

(<http://intellivoire.net/cote-divoire-le-gouvernement-sengage-a-organiser-lorpaillage/>). This is largely observed in the department of Bouna, in the Bonkani region, where there has been in recent years, a "gold rush"[3].

Driven by poverty, artisanal mining is usually done by workers with limited understanding of the long term impacts of their activities on the environment and on their health and with limited capacity to mitigate the risks. The absence of officials responsible for law enforcement and poor medical arrangements perpetuate the chaos and insecurity in the areas of gold mining [1]. Small-scale gold mining activities have been widely criticized for being wasteful, inefficient, ineffective, and harmful to the environment in addition to the illegal trade in minerals. It is commonly accepted that it is largely informal and a greater proportion of activities are illegal [4].

Social problems caused by gold mining such as crime, alcohol, sex abuse and land conflicts are also mentioned. In the rural community of Kompti in Burkina Faso for example, for the only month of July 2006, the social service has been asked to solve five rapes, six cases of drugs and eleven cases of marital conflict [5].

The aim of this study was to evaluate the environmental impact of artisanal gold mining in the Bonkani in order to improve the environmental performance of gold mining in Côte d'Ivoire. The environment being defined as *"the dynamic system defined by the physical interactions, biological and cultural, perceived or not, between humans, other living beings and all components of the environment, whether natural or processed or created by man"* [6].

2. Methodological Approach

2.1. The Study Area

The study was done in two small scale mining sites located in the Department of Bouna in the Boukani region, eastern Côte d'Ivoire (Figure 2). The population is 96,241 inhabitants [7] and the economic activities are based on agriculture. The main cash crops are cashew nuts, shea nuts and cotton whose production is almost abandoned. In terms of staple crops: yam, maize, millet, sorghum, lowland rice, beans and locust bean are grown in this region. The Department of Bouna is an area conducive to livestock which constitutes the second pillar of the economy of the Department.

The study area consists of two gold mining sites located on the lands of two villages: Lomidouo and Kintan at about 120 and 45 km south-east of the city of Bouna respectively (Figure 3).

2.2. Methods

2.2.1. Survey-Diagnosis

Since artisanal gold mining, as a socio-economic fact, cannot be understood alone, a qualitative method that favors

any or all relative to the elements was used [8]. We resorted to several techniques to collect qualitative data: direct observation, data collection, and individual or sometimes grouped semi-directive (requiring open answers) or unstructured (leaving room for digressions and spontaneous conversations) interviews. We also obtained first-hand information from various informants (artisanal miners, traders, government services, etc.).



Figure 1. Localization of the mining sites in the Department of Bouna in the Boukani region.

2.2.2. Impact Assessment

The impact assessment can be divided into three partially overlapping phases [9]: identification (identify the impacts associated with each phase of the project and activities); forecast (predict the nature, magnitude, extent and duration of the main impacts); and assessment (determining the absolute importance of impacts).

2.2.3. Identification, Description and Analysis of Impacts Detailed

After the description and analysis of the initial state of the mining sites, we proceeded with the identification of the

impacts from the checklist coupled to a matrix of potential interactions [10]. This help to find the different relationships between the sources of impacts (the various gold mining activities) and the receivers (the components of the environment undergoing disturbances compared to the initial state of the gold mining area) [11]. We used for this purpose the matrix of Leopold for potential interactions and the network diagram for induced impacts.

2.2.4. Impact Assessment

The aim of the impact assessment was to assign absolute importance to expected impacts, associated with mining activities, and determine the order of priority in which these impacts must be avoided, mitigated or offset [12]; [13]. This assessment is generally based on the key factors of the environment. In this study, the factors considered are ecological (effect on wildlife habitat, tolerance, sensitivity, biodiversity and ecosystem carrying capacity, the sustainability of local species populations) and social (effect on the health and safety of humans, loss or gain commercial value, aesthetic value, etc.). The methodology was based on the matrix of Fecteau [14].

3. Results and Discussion

The different stages of mining and processing of gold identified in both sites of gold mining were:

- 1) The prospection which consists on identifying gold-rich sites in the area; it is generally carried out by former miners who have gained experience.
- 2) Sinking or digging holes in the site that has been found to be rich in gold. This is done using rudimentary instruments and the holes are of varying sizes, depending on the richness of the site.
- 3) The crushing or reduction of the size of the mined ore; it is also done manually with the aid of hammer or anvil (granite stone). The crushers usually use knot bag to prevent the flying of particles and to protect their fingers (Photo 1).



Figure 2. Crushing of ore with a hammer or in a mortar.

- 4) The grinding which consists on reducing the ore in powder (flour) in mechanical mills (Photo 2).



Figure 3. Ore grinding.

- 5) The washing process involves mixing the flour after milling with water and washing this mixture gravimetrically on a carpet ramp in order to trap gold. The mud recovered from the carpet is cleaned until a black powder was obtained (Photo 4).



Figure 4. Washing the ground ore and recovering the sludge containing gold.

- 6) Gold recovery involves mixing the obtained black sludge with mercury. The gold-mercury mixture is then burned with a blowtorch until obtaining pure gold which is immediately weighed and sold locally to a buyer who is actually an employee of the site owner.



Figure 5. Recovery of gold by mercury amalgamation and heating for purification and weighing system.

3.1. Identification of Observed Impacts on Environment

By considering the matrix of Leopold, the potential impacts of gold mining on the environment identified in this study were classified into two categories: the impacts on the biophysical environment and the impacts on the socio-economic environment. Concerning the biophysical environment, the identified matrices were the fauna, the flora, soil and water resources. The socioeconomic environment takes into account the health, the economic and social well-being.

Twenty four percent of the potential impacts were of major importance, 39% have impacts of medium importance, and 37% are minor impacts. The major impacts are those impacting soil, landscape, and vegetation and water resources. These results showed how that small scale gold mining significantly impacts the environment.

3.1.1. Potential Impacts on the Biophysical Environment

(i). Wildlife

Throughout the duration of this study on the two sites, we have not identified the presence of wildlife. Similarly, local residents and hunters that we met reported the scarcity of wildlife in the gold mining areas.

Gold mining has a significant negative impact on wildlife (terrestrial mammals, soil microfauna, aquatic fauna, insects or even birds). This impact was due to noise from miners, disruption and destruction of animals' habitats due to the cutting of trees used to support wells, and for the construction of shelters, etc. This has led to the scarcity of certain species or their loss, and the erosion of biodiversity. The destruction of nesting sites and their niche has led to the disappearance or relocation of birds. The waterway adjacent to the sites has become totally turbid causing the depletion of aquatic species.

(ii). The Flora and Vegetation

The whole forest resources is under severe human pressure manifested by excessive deforestation for fuel wood, wood for the building of temporary shelters. There are also the clear-cut of trees for the support of mine shafts; it takes about 500 feet of tree to support wells (Fig. 7).

Two species have been identified as the most cut because of their hardness; and their interesting biological quality; shea (*Vitellaria paradoxa*) and nere (*Parkia biglobosa*). The fat extracted from shea seeds after cooking is a multipurpose product. It is used locally in food and cosmetics industry, food (chocolate), pharmaceutical. The pulp of néré rich in vitamins is an excellent food for both humans and livestock. Porridge and fermented grains are an excellent seasoning for sauces (soubala) and would have antihypertensive properties [15].

This cutting has resulted in the reduction of forest areas and the density of plant species. We observed, moreover, a clear difference between the appearance of the once closed landscape, dense and lush and today landscape characterized by increased degradation (Fig. 6).



Figure 6. Original savannah (left) and cleared savannah (right).



Figure 7. Trees cut from the savannah used to stabilize the walls of wells.

(iii). Water resources

Water is involved in almost all the activities of artisanal gold mining. During sinking, workers evacuate large quantities of water from wells with motor pumps. Milling uses in continuous water to cool engines. Washing ore consumes a lot of water; it takes about 200 liters of water to wash a bag of 50 kg of ore "flour". We can include the lives of miners, which require daily water needs (nutrition, laundry, shower,



Figure 8. Water use on the mining sites. (a) stagnant water; (b) tricycle motor transporting water from the river to the sites; (c) water use for the cooling of grinding machine; (d) river water pumped to the sites.

All these activities contribute to lower the level of the water table and the scarcity of water as resource. These activities lead also to the disturbance of the quality of the river water causing the turbidity and lowering of the river bed during the dry season flow.

Used batteries from lighting torches (the sites are not illuminated) that are often thrown into wells, mercury used to amalgamate gold, spilled oils, hydrocarbons and diesel that are seeping into ground may be carried into the nearby Binada river, adjacent to the sites or may infiltrate into groundwater. This may impact the sustainability of aquatic environment and its biodiversity.

The impacts on water are: the depletion of water resources (massive use of water, water discharges during sinking), pollution of surface water and / or groundwater

(iv). Soil and Landscape



(a)



(b)



(c)



(d)

Figure 9. Impacts of gold mining on the ground - (a) open wells abandoned, (b) bare soil eroded by trickling; (c) waste scattered on the ground; (d) earth mounds) disfiguring the landscape.

Soil is affected in one way or another at every stage of artisanal gold mining. The physical impacts left following the completion of the wells, forming heaps and deforestation that results negatively influenced the quality of soil. We can add the presence of solid and liquid waste on the site (household waste, oils, hydrocarbons, human faeces, plastic, wastewater, etc.). All these result on the erosion and loss of soil fertility, the contamination by solid and liquid waste, and the degradation of the landscape.

(v). Air

Several activities are source of air pollution particularly grinding the ore. Indeed, workers have no protective mask while the fine powder is easily transported by wind. Huge emissions of gases were observed, fumes but also noise (mills, pumps and motors). Air may be polluted by mercury vapors from burning amalgamated gold. Mercury is used to extract gold from ore by forming a mixture of approximately equal parts of gold. Mercury is then heated, leading to its evaporation and gold is collected. This emitted Mercury may represent a significant source of air pollution. The air content of mercury vapor around the points where the amalgam is heated can reach very high values and can almost always exceed the limit set by the [16] ($1.0 \mu\text{g} / \text{m}^3$) for the Exposure of the general population.

The decomposition of solid and liquid wastes produced by miners generates strong odors. These wastes are dumped into the wild without any sanitation measures (Photo 9). Despite the facts that such pollution is felt by the concerned population, no protective measures are taken by small-scale miners to reduce or control them.

(vi). Health

Miners are mostly exposed to a number of diseases that are related to their living and working condition on the mining sites. According to a private medical office located on one site, miners presented a number of diseases that are related to the lack of sanitation and hygiene in both sites, but also many accidents occurred. Malaria is due to the presence of stagnant water from the toilet. Diarrheal diseases, typhoid and cholera, are caused by poor hygiene. Skin diseases are caused by abrasions and ore jets during the sinking and crushing

operations. Respiratory diseases (cough, pneumonia, angina, etc.) are caused by dust exposure especially during grinding and drilling. This can affect children who accompany their mothers on the sites (Photo 9).

Water used in the sites is supplied from the river or from stagnant water. This lack of hygiene characterized site restoration, both individuals and providers, in terms of drinking water quality and the management of household waste. Meals served in restaurants: cereal, rice, pasta and beans or canned are often poorly conditioned. The individual food ration is insufficient and does not compensate for the efforts made by the miners during the day.

Exposure to mercury during the amalgamation represents a real public health problem. Studies on the use of mercury in mineral processing conducted on 11 gold mining sites in Burkina Faso [17] illustrated the impact of artisanal mining on health. The average value of mercury is found to be 194.5 mg/g in the urine. More than 98.9% have urinary concentrations of mercury beyond the reference values for the general population; 68.8% have concentrations beyond the professional reference values (35 mg Hg/g), and almost half (49.5%) presented values above 100 mg Hg/g.



(a)



(b)



(c)



(d)

Figure 10. Waste dumping site, wastewater from latrine (haut) and women with their baby, crushing ore in a pestle.

Several cases of STI/AIDS were reported by the private health center located on the sites, even if there were no screening session. Prostitutes encountered on sites reported using adequate methods of protection. The STI/AIDS come from the luxury prostitution of salesgirls who become prostitutes at night, lured by the easy money especially during good production period. This is favored by alcohol and drugs and these girls will go with miners unprotected and who constantly are changing partners.

Studies elsewhere indicated that the number of women with STIs identified was more than 4 times higher than that of men in the same age group [18];[4].

Noise pollution is also encountered in the sites, due to vibration produced by the digging of wells, ore crushing and grinding, the operation of some machines such as mills, power generators, and exhaust pipes, etc. This noise that exceeds the regulatory standards has very negative consequences, not only on human health but also on wildlife. Local people have no means of protection against noise and vibration.

3.1.2. Potential Impacts on the Socio-economic Background

(i). The Economy

Gold mining is important for the economy of miners and the local communities. This activity mostly has a very positive impact on jobs. When the activity is profitable, according to the authorities of the sites, up to 100 - 150 workers excluding daily laborers can be found. This number can drop to 50 or even 20 when another site is found more productive. Workers on the sites are very mobile and most workers on the sites are from the countries of the sub-region where the activity of gold extraction is a tradition. Therefore money obtained is often repatriated to their countries of origin.

The sale of gold extracted from a bag of ore can earn up to 10 million CFA (17 200 euros). Although we have been unable to obtain information on the income of workers in the whole chain, gold panning help to increase the incomes of miners through direct sales of gold. Of the 76 workers interviewed, about 30.3% said they have sent money to their families and that this money have been used to deal with household

expenses (children's education, food and health), 10, 57% spent on food in working sites, 26.3% of respondents said they spent their income for food, for clothing (23.7%), and 10.5% for personal items (Table 1). This study found that most miners have ventured into mining as a survival strategy rather than as a long term investment.

Table 1. Goods and services purchased using money from the sale of gold.

Expenditures	Number of Respondents	Percentage
Electrical gadgets	7	9,2
Schooling and hospitalization	5	6,6
Fun and recreation	4	5,3
personal items	8	10,5
Shipping money to the family	23	30,3
Food	15	19,7
Clothing	7	9,2
Investing in real estate	2	2,6
Gear wheel	3	3,9
Other	2	2,6
Total	76	100



(a)



(b)



(c)



(d)

Figure 11. Commercial activities on the mining sites- (a) food; (b) grocery, (c) butchery; video club.

Gold mining contributed also to the creation of additional activities that have developed around the sites. On both sites, we have identified restoration, butchers, bars, shops, blacksmith and mechanics, clothes sellers, clubs and video games, and fruit and vegetables sellers.

(ii). Social

Talks we have had with the site leaders and traditional authorities, it appears that the holders of the sites are very involved in local communities. Thus, a percentage (which has not been given to us) from the sale of gold would be returned to the sites, the villages and to the royalty of Bouna. This commitment also involves the construction of school infrastructure and sponsorship of sporting activities.

But gold mining also causes loss of agricultural land and deforestation, which negatively impact on the local economy.



Figure 12. Children working on the mining sites.

Gold mining at both sites also has a negative impact on people especially women and children. Indeed, on both sites we found the use of children for certain tasks such as crushing and transporting the ore. The girls say they work for parents who live in the surrounding villages (Photo 11). We have not been able to obtain information about the level of their remuneration, but they are paid by task. They come every morning to go back the evening, often without finding work and without enough money to afford a meal. In these situations they are at the thank you of any worker who makes them advances by paying their meal. According to

indiscretions, this resulted in some cases of sexual abuse.

(iii). On Security

The impact of gold mining on safety is related to the working conditions on the site and facilities. The lack of personal protective equipment increases the risk of injury. Possible electrocution due to the outdoor exposure to power lines (Kintan site) and which may affect the safety of people on the site (fire hazard). Banditry and insecurity are virtually present. The presence of many two-wheeled vehicles (carts, motorcycles) often causes accidents that can in some cases cause irreversible trauma.

Crime and violence are common currency so that the holders of the sites use the police (Republican Security Force) to provide security at the sites. Traditional authorities as well as officials at the sites do not have the means to control deviant behavior among migrant minors [19]; [20].

4. Recommendations

The recommendations aimed at the rehabilitation of the sites after the closing of the sites by reforestation and helping miners master the new technologies through technical supervision and monitoring. This requires helping miners to use mercury trap which is a device uses that reduce the release of mercury vapor in the atmosphere. It is an assembly of plumbing parts in which the amalgam is burnt; mercury vapor passes through a tube and is condensed in a cooler [21].

It is also possible to teach the miners how to use mercury-free gold extraction technologies such as chlorination. This has been tested in Guyana and has resulted in a recovery rate of over 93% in the laboratory.

In terms of hygiene and security, we must develop a simple policy of solid and liquid waste management. Household waste can be buried in pits and used to make the traditional composting beneficial to farmers in village guardian's sites.

In terms of health, we propose that the owners of the sites undertake campaign of education of miners and the population on the importance of using and building effective systems for on-site sanitation: namely to equip the toilet for a good management of their excreta. This type of installation can also be built by the owners of the sites to ensure the health of users. Besides that, programs focusing on HIV/STI prevention, with targeted interventions for high risk women such as the one found in both sites, will be extremely important in such high transmission communities where there is substantial recent migration of men and women seeking work. Such programs can be initiated by a private/public/NGO partnership.

Institutionally, the state should define a consistent policy of artisanal gold mining taking into account the environmental, social and health.

5. Conclusion

The results of the studies have shown that working conditions are generally dangerous and unsanitary and deplorable living conditions in traditional gold mining

systems. Internal costs of small-scale mining borne directly by minors include the poor conditions of health and safety in mines. External costs are supported by the surrounding communities, such as the degradation of the environment around the mining area and social disruption in the form of prostitution and alcoholism. Riparian Communities mines suffer environmental degradation and social problems. These negative impacts will remain for a long time in the areas of mining sites long after the miners have abandoned sites.

However, the resilience of the gold mining activities has proven to be one of the main sources of livelihoods in local communities of the extraction sites because they provide income and employment for survival from day to day. Panning for gold is proving to be a very important activity; it also creates many direct and indirect jobs such as catering and distribution. Unfortunately, these activities do not generate revenue for the national treasury, although they participate in local development through donations and infrastructure construction.

If gold mining to continue, there must be reconciled with the preservation of nature and its occupants. This should be a concern for policy-makers, technicians, civil society, traditional and religious leaders, miners who must work each for good organization of this carrier activity. The State shall for its part, promote research and made available on fair and necessary information to establish appropriate policies for the mining sector and train human resources with the ability to monitor compliance with environmental standards.

In overall, the sustainability of small-scale gold mining is a contentious issue given the level of environmental degradation and the disruption of social relations taking place in the district. However, the sustainability of the sector mainly rests upon proper regulation by the national government in order to improve monitoring mining activities and remitting of revenue to the fiscal.

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