Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2022, 9(9):1-8

Research Article ISSN: 2394 - 658X

Environmental Management of Silmiougou (Burkina Faso) Artisanal Gold Mine Waste

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ABSTRACT

In Burkina Faso, artisanal mining is practiced in all thirteen (13) regions. The country made 2,262 million USD gold exportation in 2019 against 3,568 million USD in 2020. Today, with more than 500 active sites, artisanal gold mining employs over a million people. The studied site is located in the rural commune of Silmiougou in the department of Boussé (Burkina Faso). The artisanal mining site of Silmiougou open in 2014. The waste produced on the site is generally not managed with crushing and grinding phase employing more children. The latter are exposed to injuries from flying stones, respiratory illnesses from dust and deafness from noise. Skin infections can also occur from repetitive contact with ore flour, waste oils and other hydrocarbons. During the ore washing and refining phases (amalgamation, burning and cyanidation), unprotected handling and continuous exposure to chemicals can be sources of mercury and cyanide poisoning. Measures must be taken to support or compel the artisanal gold miners for the proper management of the Silmiougou site. These measures include the enforcement of regulations on gold panning by emphasizing the environmental aspect and ensuring compliance with existing laws along with the technical supervision of artisanal gold miners.

Key words: Artisanal mining, Environment, Burkina Faso, Safety, Management

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1. INTRODUCTION

Burkina Faso, in addition to being an agricultural country, has become for more than a decade a country with strong mining potential [1]. There are many mineral resources and the most known are gold, zinc, copper, manganese, phosphate and limestone [2]. Gold has been the most exploited mineral and the country's leading export product since 2009 [3]. Burkina Faso ranks 5th among gold producing countries in Africa after South Africa, Ghana, Mali and Tanzania [4]. The ministries in charge of mines, finance and the environment mainly manage the mining sector. Mining activities are governed by legal texts, the main one being the 2015 mining code adopted through Law No. 036-2015/CNT of June 26, 2015. Several countries in West Africa derive a large portion of their government revenues from their natural resources, including gold. While the precious metal is mainly mined industrially, artisanal gold mining commonly known as "gold panning", often clandestine and illegal has been on the rise in recent years. In Burkina Faso, artisanal mining is practiced in all its thirteen (13) regions. The country made 2,262 million USD gold exportation in 2019 against 3,568 million USD in 2020 [5]. With more than 500 active sites, artisanal gold mining employs over a million people [2, 5, 6]. Notwithstanding the provision of substantial income, which improves the living conditions of the populations by attracting them, artisanal gold mining has harmful consequences for man and his environment. In fact, in Burkina Faso, particularly in Silmiougou, the extraction of the precious metal takes place in several stages and each stage generates waste that is for the most part dangerous for the environment [1]. What then is the impact of artisanal gold mining on the Silmiougou site? The responses given to this question will be the main objective of the current article.

2. METHODOLOGY

2.1. Presentation of the site

The site is located in the rural commune of Silmiougou in the department of Boussé (Burkina Faso). The artisanal mining site of Silmiougou open in 2014. It covers an area of about one km^2 and the company "Comptoir des Métaux Précieux (CMP) SARL" owns it [7] (Figure 1). The relief of the region is generally flat with a few armored hills. The soils are mostly ferruginous in nature. The climate is Sudano-Sahelian with an average annual rainfall of between 600mm and 800mm of water. The natural vegetation of the region consists of shrub savannas on the plateaus, wooded savannas in the valleys and galleries along the rivers. According to Castaing [8], the geology of the region is marked by the presence of massive granites and various volcanosediments in the form of belts most often oriented South-West and North-East. On the site itself the presence of outcrops of porphyritic biotite granites was noticed. Overburden is generally saprolite and meta-andesites with a significant sheet of water 70m deep [8].

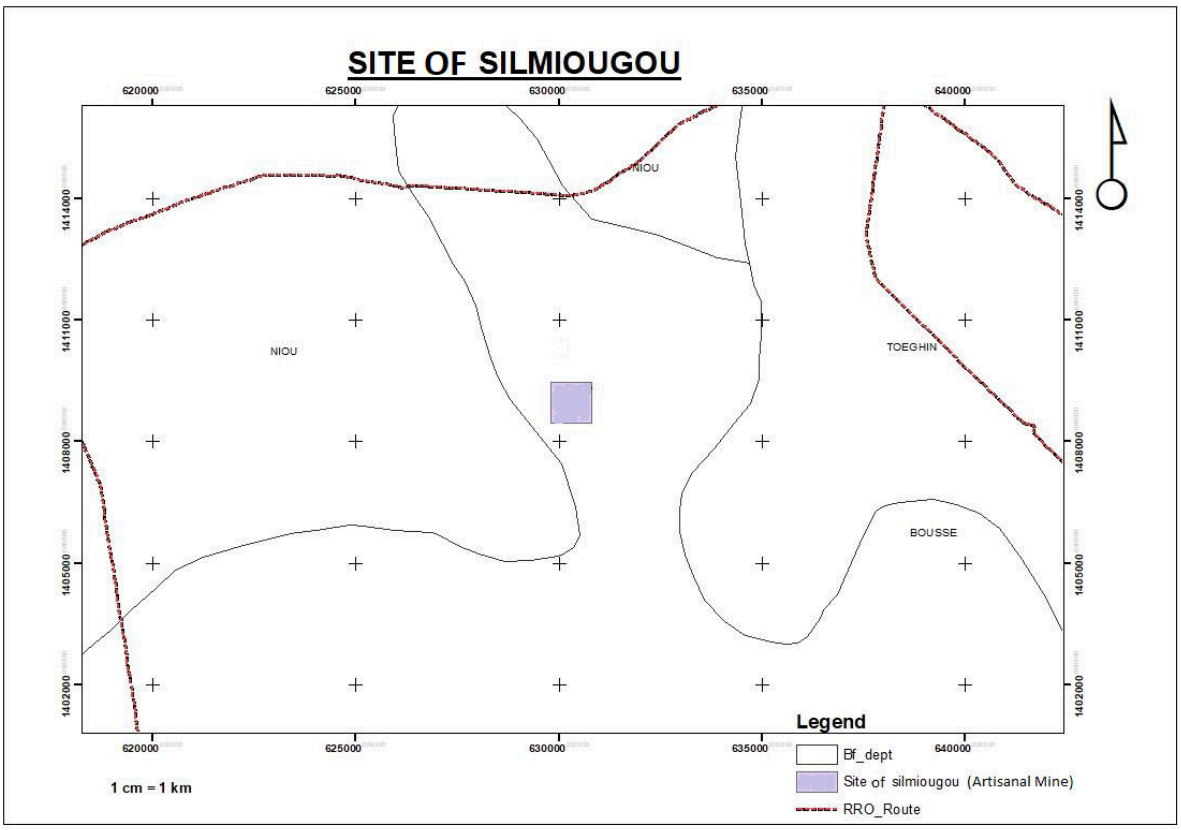

Fig. 1 Map of the Silmiougou operating site

2.2. Main activities in the site

2.2.1. Shaft sinking

Digging or sinking is the process of digging mining shafts (Figure 2) by artisanal miners. The objective being to reach the ore, which is at a depth relative to the dip of a vein. It is the hardest job in artisanal gold mining. The means used are limited to rudimentary tools consisting of pickaxe, shovel, chisel, sledgehammer, hammer, torch, motor pump and sometimes dynamite (for explosions), rope and pulley to lift the ore (Figure 2). The hole is equipped with an aeration system powered by a battery connected to a solar panel. When the hole reaches a water table, the water is evacuated out of the hole using a pump and this water is used to wash the ore. The overburden is piled in the open air and the holes are abandoned after removing the ore.

Fig. 2 Silmiougou artisanal mining hole

2.2.2. Crushing

Once out of the pits, the blocks of rock containing the ore are put in 50 kg bags and then transported for their crushing. Transportation is made by motorcycles and tricycles. The crushing is done manually or using small grinders to have a centimeter to millimeter particle size. At this level, the waste produced is generally tons of dust loaded with heavy metals such as lead. On the Silmiougou site, those who practice the crushing are not self-protected.

2.2.3. Grinding

Final crushing consists of reducing the already crushed ore to powder in order to facilitate the extraction of gold. To obtain fine particles, the already crushed ore is crushed two to three times. Grinding is done using a mill as shown in Figure 3. Operators who do not have enough means to hire the services of a mill crush the small blocks of ore in a mortar with a pestle. At this level, the waste produced is generally tons of dust loaded with heavy metals such as lead.

Fig. 3 Ore crusher in the Silmiougou mine

2.2.4. Washing

It is an important step in the exploitation of the ore. It consists of washing the crushed ore gently with a jet of water. It is done on a board whose upper edge is placed on a drum (barrel) and the lower edge is routed to a retention basin (Figure 4). Thus, it forms an inclination facilitating the wash. The purpose of washing is to rid the ore powder of any impurities and to facilitate the agglomeration of the ore by the mercury. Before starting washing, the ore is mixed with water with the addition of detergent (soap). The concentrate obtained is treated to recover the gold. The light material is drawn into the basin that still contains unrecovered grains of gold. Its content is gradually piled up in front of hangars to be sold to operators using the cyanidation technique. These sludge can be stored for a long time while waiting for a possible buyer. The heavy metals and sulphide minerals they contain can be transferred to the groundwater or surrounding environments after rainfall.

Fig, 4 Ore washing

2.2.5. Mercury amalgamation

The amalgamation occurs just after obtaining the final concentrate following washing. A few drops of mercury are mixed with the concentrate to obtain the gold-mercury amalgam. The whole is washed several times to remove the silver-colored gold-mercury amalgam. At the Silmiougou site, amalgamation process is done in the open air without any self-protection.

2.2.6. Burning or refining

This is the last phase to dispose of the gold ore. It consists of heating the gold-mercury amalgam obtained with a blowtorch on a gas bottle or on a stove. The goal is to obtain gold for weighing while removing the mercury by evaporation. This purification process makes it possible to obtain gold devoid of any impurity.

2.2.7. Cyanidation

This method is more expensive than mercury amalgamation. The sludge resulting from the washing of the other artisanal gold miners is used to recover the gold. This is the most dangerous activity in the gold panning chain. It consists of extracting gold from ores in a basin using a cyanide solution. The products used are cyanide, sulfuric acid, nitric acid and zinc chips [9]. The cyanidation is done in rectangular basins about 1.5 m wide, 2.5 m long and 0.5 m deep. These pools are arranged two by two. Between the 2 pools is a small pool commonly called a “swimming pool” 0.5m wide, 1m long and 1.5m deep (Figure 5). The bottom and walls of large pools are generally lined with waterproof tarpaulins to prevent infiltration. The bottom and walls of the pools are coated with a thin layer of cement. One (01) Kg of sodium cyanide

(NaCN) pellets is spread in each basin and mixed with water. The water-cyanide-ore mixture is left for a whole day for cyanide dissolution and cyanide-gold reactions. The cyanide-gold liquid is directed through small orifices to U-shaped tubes containing the zinc chips (Figure 5). The cyanide water overflowing from the tubes of the swimming pool is drawn with a sump then poured back into the large basins. After three (03) days, the tubes are removed from the pool and the gold-rich zinc is put in bins. A solution of sulfuric acid is poured into the containers containing the zinc. Sulfuric acid reacts with zinc to form a concentrated solution. Nitric acid is added to the gold-rich solution to clean out impurities such as iron and aluminum. There is a violent reaction giving off reddish smoke (hydrocyanic acid HCN) after the addition of nitric acid. In the containers, water is added and the mixture is left to stand for at least 2 hours. After decantation, the concentrate is put in aluminium tanks and heated at high temperature for at least 4 hours. The ashes obtained are then transported to Ouagadougou in the foundries to recover the gold. The cyanide sludge resulting from this treatment is either resold to other miners for possible recovery with activated carbon or abandoned on site without any management.

Fig. 5 Cyanidation ponds with U-shaped tubes containing the zinc chips arranged in the pool

3. RESULTS AND DISCUSSION

The waste produced on the site of Silmiougou is generally not managed. However, some miners wash their ore next to the old holes and the mud resulting from their washing is used to fill back the holes (Figure 6). The site managers suggest that all gold miners fill the old neighboring holes with the overburden from their holes. Unfortunately, this recommendation is not well followed.

Fig. 6 Former artisanal mining holes filled with the washing sludge at Silmiougou site

Throughout the mining activity, there are health risks [10]. It was found that the miners did not utilize protective equipment and they were not taking precautionary measures in their tasks. During the shaft sinking phase, dust and

moisture in the holes can cause respiratory infections. The use of dynamites can also cause respiratory issues. During the rainy season, the risk of landslides is high because the rock is no longer stable [11]. This can cause suffocation due to lack of oxygen in the holes. These holes left everywhere can cause serious accidents to humans and animals. The crushing and grinding phase employs more children. The latter are exposed to injuries from flying stones, respiratory illnesses from dust and deafness from noise. Skin infections can also occur from repetitive contact with ore flour, waste oils and other hydrocarbons. During the ore washing and refining phases (amalgamation, burning and cyanidation), unprotected handling and continuous exposure to chemicals can be sources of mercury and cyanide poisoning [12]. For mercury, the burning of amalgam is the main source of exposure to mercury vapor. This poisoning due to mercury can cause illnesses such as tremors, brain deterioration, kidney failure, etc. [13]. As for the amalgamation, which is done with bare hands, it also exposes the actors to skin poisoning. Concerning cyanide, it should be noted that artisanal miners handle cyanide pellets and clean out cyanidation ponds without gloves, which increases the risk of poisoning. The animals that drink the water from the basins die a few minutes later and the miners eat these same animals. Unlike mercury, cyanide does not accumulate in food chains but is very harmful because it prevents the cells of the body from using oxygen, which causes them to die [14]. It is therefore more dangerous for the brain and the heart. The severity of symptoms depends on the exposure time and the concentration of this chemical agent. It can enter the body orally, through the skin and by inhalation. Its symptoms (headaches, dizziness, cardio-respiratory arrest) evolve very quickly and can cause death in a few minutes. Inhalation of HCN vapors or ingestion of 200mg of KCN or NaCN results in rapid death from respiratory arrest [15, 16].

Environmentally, the risks are enormous. In fact, the abandoned holes constitute an influence on agricultural land. Dust produced from crushers and grinders degrade the air quality in the area. In addition, abandoned holes can cause serious human or animal accidents and expose the groundwater to possible pollution from the surface. To this, we can add the depletion of underground water resources, which is a rare commodity in the area. The most environmentally hazardous element at the site is cyanide. The waste rock contribute greatly to the pollution of soil, surface water and groundwater. In fact, this waste exposed to the mercy of rain and air can cause acid mine drainage (AMD). We also note the presence of heavy metals. This causes the deterioration of crops that are close to or located downstream from the basins. There is the loss of leaves and the cessation of growth and even the death of certain species of trees. Aquatic organisms such as fish and aquatic invertebrates are most sensitive to cyanide [17]. A concentration of free cyanide of the order of 5 to 7.2 µg/L in the aquatic environment inhibits the reproductive system of many fish species [18]. Only algae and macrophytes are more resistant to free cyanide in the environment [17].

Several measures can be taken for better management of the site such as:

- Awareness of health risks,
- Use protective equipment,
- Backfill old holes with waste rock,
- Use impermeable membranes in cyanidation ponds,
- Cover up cyanide sludge deposit,
- Use alternative processes to cyanidation less dangerous such as Aqua Regia [19], Thiocyanate process [20], Thiourea gold process [21] and Thiosulfate process [22].
- Plant herbaceous such as lemongrass around cyanidation ponds,
- Secure the perimeter surrounding the cyanidation tanks to prevent children and animals from having access to them.

Measures must be taken to support or compel the artisanal gold miners for the proper management of the site. These measures include the enforcement of regulations on gold panning by emphasizing the environmental aspect and ensuring compliance with existing texts. The awareness raising of artisanal gold miners on the proper use of cyanide and the benefits they will have in protecting the environment, the technical supervision of artisanal gold miners, the technical team responsible for monitoring and supervising gold panning activities with real means to carry out their work in the field must be a key point to the success in the environment protection.

After exploitation, the site must be restored. For this, all the holes must be backfilled and all the installations demolished. Herbaceous such as lemongrass on the sludge from the cyanidation ponds can be used. As for the residues resulting from mercuration, one can proceed by a demercuration. At the end, there can be a revegetation of the site with *Citrus sinensis* [23]. Nearby groundwater and surface waters should be analyzed to check their pollution profile. Finally, the site must be monitored after its closure by a rehabilitation team.

4. CONCLUSION

Mining is booming in Burkina Faso. This exploitation is done in an industrial and artisanal way. The mining operations present risks to the environment and to society, which are aggravated mainly by factors relating to artisanal gold mining activities such as:

- the rapid development of gold panning which escapes the control of the State;
- the conditions of the natural environment favorable to risks/vulnerability;
- the inappropriate operating techniques used (methods used by the miners of Silmiougou to extract gold);
- the insufficient quality of the preliminary studies carried out, or even the lack of mastery of the methods for studying risks and hazards;
- the lack of adequate environmental monitoring of the activities of the mining works and infrastructure;
- the level of poverty of the population and lack of means and the non-compliance with regulatory requirements.

The risks and consequences of non-compliance with environmental requirements are essentially related to human health; social peace; resources and the environment (water, soil, flora, fauna, etc.).

Acknowledgements

This study was supported by the University of Fada N'Gourma (Burkina Faso).

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