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Technical Evaluation of Gravity Separation Efficiency in Gold Ore Treatment: Evidence from the Boena Artisanal Mining Site, Burkina Faso

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Abstract

This article focuses on the evaluation of the efficiency of gravimetric processing of gold ore in an artisanal mining of Boena, carried out at the laboratory of Université Yembila Abdoulaye TOGUYENI (UYAT) in Fada N'Gourma, Burkina Faso. The treatment was performed using the sluice box gravimetric separation method, starting from a 3.3 kg residue from a first sluice processing run, with 15 litres of water. The equipment used includes a hammer, a sieve, a sluice box fitted with mats, gloves and a gold pan. At the end of the treatment, no native gold was found in the recovered concentrate, only iron oxide as hematite (Fe_2O_3) and magnetite (Fe_3O_4). This outcome is explained by the nature of the sample: as a post-gravimetric residue, it had already been depleted of free gold during the initial treatment. The sluice nonetheless correctly performed its heavy mineral concentration function, confirming the reliability of the process. This study highlights the limitations of double-pass sluicing on residue material and underscores the importance of prior ore characterization before processing.

Keywords: Gravimetric processing; sluice; artisanal mining; hematite; magnetite; Boena, Burkina Faso.

Introduction

Globally, more than 43 million micro-miners, small, medium, and large artisanal miners extract at least 30 different minerals in rural areas of developing countries. Approximately 20 million people in more than 70 countries are directly involved in artisanal gold mining, with gold production estimated at between 380 and 450 tons per year[1]. Burkina Faso signed the Minamata convention on mercury on October 10, 2013 and ratified it on April 10, 2017. The objective of the convention is to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds[2]. Artisanal gold mining plays a significant role in the rural economy of Burkina Faso[3]. However, it relies on unsuitable techniques that result not only in low gold mineral recovery but also in substantial tailings production and environmental degradation. Gravimetric sluice treatment is the most widespread concentration technique among artisanal miners due to its ease of implementation, affordability, and the absence of chemicals[4].

However, its effectiveness is directly dependent on the nature and mineralogical composition of the ore being treated, particularly the free gold content and particle size. Gold processing in a sluice (washing ramp) relies on gravity separation. Crushed ore is mixed with water and flows over an inclined surface equipped with washing mats and riffles. The denser gold particles are trapped while the waste rock is removed[5].

Controlling mercury emissions throughout the artisanal mining lifecycle was a key factor in the development of the Minamata Convention. Among the Convention's key provisions is the international regulation of the artisanal and small-scale gold mining (ASCM) sector. This study on the evaluation of the effectiveness of gravimetric treatment of gold ore from the Boena artisanal mining site was conducted at Yembila Abdoulaye TOGUYENI University (UYAT) in Fada N'Gourma. It is important to note that the ore sample used for the gravimetric treatment was a residue from the sluice treatment carried out at the Boena artisanal mining site. The main objective is to determine whether this residue still contained gold recoverable by gravimetric analysis (sluice), and to analyze the factors explaining the results obtained.

Materials and Methods

Site Presentation: Boena is a village in the Boudry department, in the Ganzourgou province, in the Oubri region. The village is located about fifty kilometers south of the town of Zorgho (the capital of Ganzourgou province) (Figure-1)[6]. Boena is primarily known for its artisanal mining site, which attracts many miners in search of precious metals. This artisanal mining activity gives the village significant economic importance in the region. The artisanal mining site used for our study is located at the following UTM coordinates (X: 0741232m, Y: 1326095m) and altitude (Z: 301m). The landscape is typical of the Sudanian-Sahelian zone, with savanna vegetation and a climate with two

seasons: dry and rainy. Boena offers an ideal setting for learning about the gravity processing of gold ore.

Gravimetric Sluice Processing Principle: Gravimetric processing is a physical separation method based on the density differences between the mineral species in a sample[7]. The sluice is an inclined channel through which a stream of water carrying pulp (a water-ore mixture) flows. The density difference between the minerals causes them to separate: lighter minerals (gangue) are carried downstream by the current, while heavier minerals (gold, hematite, magnetite) are retained in the mats by gravity[8].

The efficiency of the separation depends on several factors: the relative density of the minerals present, the particle size distribution of the ore, the water flow rate, the channel's inclination, and the nature of the retained mats[9].

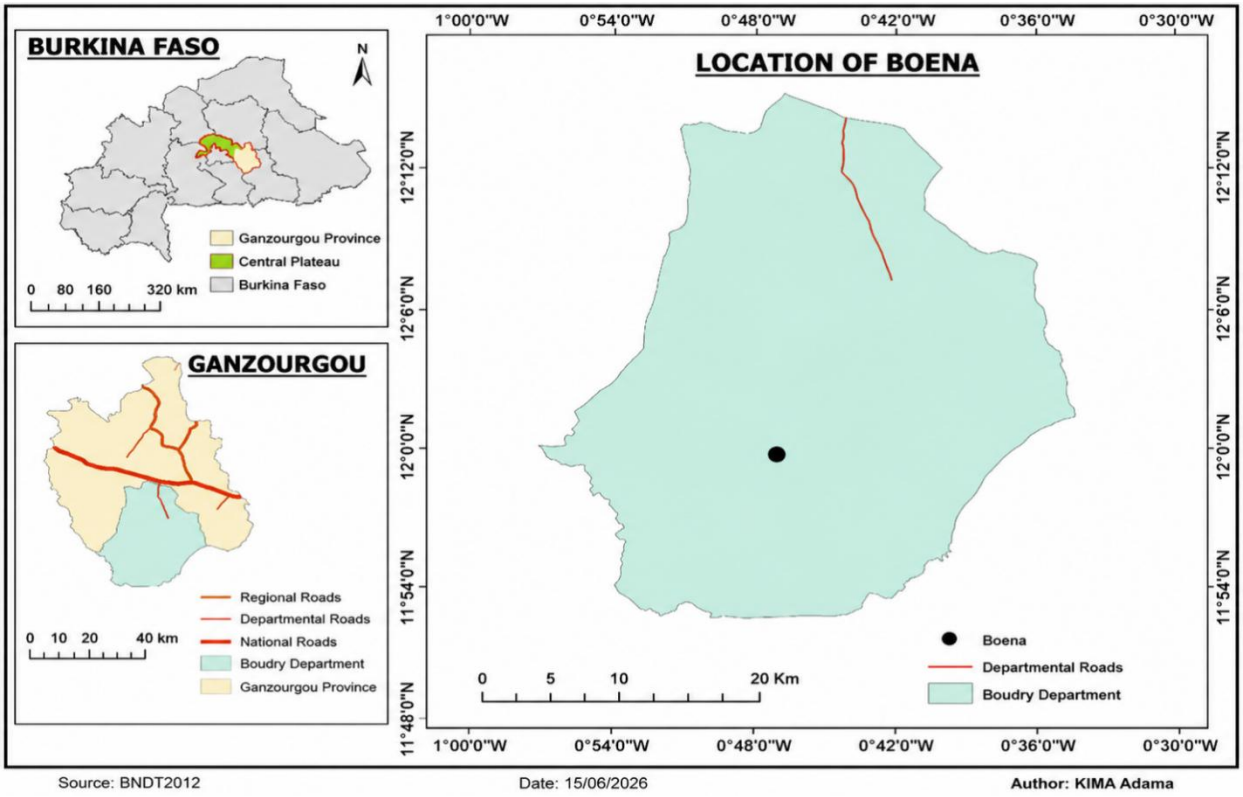


Figure-1: Location map of Boena.



Figure-2: Artisanal miners working with sluice boxes[2].

The experimental protocol implemented during this practical work is as follows:

A 3.3 kg sample of ore that had already undergone initial gravimetric treatment on a sluice was subjected to a second treatment to evaluate its effectiveness (Table-1). We used 15 L of water throughout the ore washing process. The feed rate of a sluice depends on its width, the water flow rate, and the pulp density. The relationship between the height (H) and width (W) of the sluice walls is generally H = 0.3W.

At the end of the feeding process, the mats were carefully removed and rinsed in a container to recover all the dense particles that had been trapped within them. Generally, in gravimetric concentration processes, the gold content of the concentrate is even inversely proportional to the recovery.

The recovered concentrate was panned to refine the separation and macroscopically identify the heavy minerals obtained by visual observation (color, luster, streak).

Table-1: Characteristics of the experimental protocol used.

Parameter	Value
Sample type	First-pass sluice residue
Ore mass	3.3 kg
Water volume used	15 liters
Angle of inclination	≈ 12°C
Method applied	Gravimetry on sluice

Results and Discussion

Mineralogical Interpretation: After macroscopic analysis of the final concentrate, we detected the presence of iron oxides such as magnetite and hematite (Table-2 and Figure-2). However, we were unable to detect the presence of gold particles, which was our target element. The most significant result of this treatment is the complete absence of native gold in the final concentrate.

This result is explained by the nature of the sample treated: it is a residue from a first pass through a sluice. In accordance with the principle of the gravimetric method, the recoverable free gold had already been extracted during the initial treatment. The second pass could therefore logically not produce gold, except in the case of significant losses during the first treatment[10].

This interpretation is consistent with general observations made at gold panning sites in Burkina Faso, where a significant portion of the gold contained in the treated ore remains trapped in the tailings in a form that is difficult to recover using rudimentary gravimetric equipment[11].

The exclusive presence of iron oxides such as hematite (Fe_2O_3) and magnetite (Fe_3O_4) in the concentrate is, however, expected and easily explained. Hematite, with a density of 4.9 to 5.3 g/cm³, and magnetite, with a density of ≈ 5 g/cm³, is a heavy mineral widely distributed in lateritic formations and rocks of the Birimian belt of Burkina Faso[12]. Its density, although significantly lower than that of gold, is high enough to be retained by the sluice gates, unlike the lighter minerals of the gangue (quartz: ≈ 2.65 g/cm³; feldspars: ≈ 2.55–2.76 g/cm³)[13].

These observations are consistent with previous studies, which emphasized that the efficiency of gravimetric treatment is directly linked to the mineralogical composition of the ore fed and that the residues of first concentration generally contain heavy minerals that cannot be recovered (hematite, magnetite) in the absence of residual free gold[7]. The Figure-3 shows the result obtained after the panning.

Table-2: Gravimetry processing results.

Expected mineral	Mineral obtained	Macroscopic observation: Reddish-brown to black color, metallic luster, red streak.
Native gold (Au°) — density ≈ 19.3 g/cm³	Hematite (Fe_2O_3) density ≈ 5.3 g/cm³	Black to brown color, metallic luster, red streak.
	Magnetite (Fe_3O_4) density ≈ 5 g/cm³	Macroscopic observation: Reddish-brown to black color, metallic luster, red streak.



Figure-3: Deposits obtained at the end of the panning.

Analysis of Processing Efficiency: The efficiency of a processing method is measured by its recovery rate of the component of interest. In this case, the gold recovery rate is zero (0%).

However, this value should not be interpreted as a failure of the process itself, but rather as the logical consequence of the absence of gold in the feed ore. Gravimetric sluice treatment applied to the ore tailings did not recover gold, but only iron oxides (magnetite, hematite)[14].

This result can be scientifically explained by the depletion of free gold in the ore during the initial treatment. The sluice process functions correctly, but its yield is dependent on the composition of the input ore[15].

The sluice correctly performed its function of concentrating heavy minerals, as evidenced by the presence of hematite and magnetite in the concentrate[16].

Its density separation efficiency is therefore confirmed. This result illustrates a fundamental principle of mineral processing: the efficiency of a processing method is inextricably linked to the quality and composition of the fed ore[17].

Based on the results obtained during gravimetric treatment, we recommend the following: Working with fresh, untreated ore samples to ensure the presence of recoverable free gold; systematically measuring and monitoring all operating parameters (inclination, flow rate, particle size); Performing preliminary mineralogical characterization by XRD or microscopic observation before any treatment operation; Supplementing macroscopic identification with instrumental chemical analyses.

Conclusion

This study aimed to evaluate the effectiveness of gravimetric sluice treatment of gold ore in an artisanal mining context. The relentless pursuit of profit exposes miners working in the EMAPE mine to the risk of mercury exposure. This must be addressed through information campaigns, not only on the risks of mercury exposure, but also on alternatives to mercury use and, on the measures, taken to reduce mercury releases, emissions, and exposure within the framework of this plan.

Performed on 3.3 kg of ore from a first sluice pass, with 15 liters of water, this second treatment failed to recover any native gold particles. The resulting concentrate consisted exclusively of iron oxides (magnetite and hematite).

This result confirms two fundamental principles of mineral processing. First, the sluice is an effective device for concentrating heavy minerals: it successfully retained the dense hematite and magnetite, while allowing the lighter minerals to escape from the gangue. Second, and more fundamentally, the effectiveness of a processing method is always dependent on the nature and composition of the feed ore. A post-gravimetric residue is, by definition, depleted of recoverable free gold using this method.

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