# Characterisation of Small-Scale Gold Mining Tailings in the Western Region of Ghana*

[1]I. J. Cobbinah, [1]G. M. K. Gbedemah, [1]Z. K. Nurudeen, [1]A. K. Saim, and [1]R. K. Amankwah
[1]University of Mines and Technology, Box 237, Tarkwa, Ghana

Cobbinah, I. J., Gbedemah, G. M. K., Nurudeen, Z. K., Saim, A. K., Amankwah, R. K. (2021), "Characterisation of Small-Scale Gold Mining Tailings in the Western Region of Ghana", *Ghana Mining Journal*, Vol. 21, No. 2, pp. 27-32.

## Abstract

On average, small-scale miners can recover gold ranging from 20% to 70% of the total available gold by the conventional gravity separation methods only. As a result of this, tailings materials from Artisanal Small-Scale Gold Mining (ASGM) operations contain a significant amount of gold, and characterisation of these materials would inform metallurgical decisions concerning reprocessing of the tailings from ASGM. In this study, size-by-size analysis, gold grade, gold deportment, and cyanidation studies were carried out on ASGM tailings samples collected from five different locations (Asankragua, Bogoso, Prestea, Wassa-Akropong, and Tarkwa) in the Western Region of Ghana. Head grades of tailings samples from Asankragua, Bogoso, Prestea, Wassa-Akropong, and Tarkwa were 1.84 g/t, 4.12 g/t, 0.45g /t, 0.17 g/t, and 5.97 g/t, respectively. The 80% ($P_{80}$) of the tailings materials passed through 1.797, 0.578, 1.636, 3.210, 0.380 mm screen sizes for samples from Asankragua, Wassa-Akropong, Tarkwa, Prestea and Bogoso, respectively, with an average of 1.52 mm. Also, the gold deportment analysis revealed that the highest metal distribution of 42.03% in -106 µm size fraction for samples from Bogoso, followed by 31.0% for Wassa-Akropong, 29.7% for Tarkwa, 27.0% for Prestea, and 22.0% for Asankragua. It was shown after cyanidation test works that the highest gold recovery was 81.5%, 72.3%, 75.3%, 65.6%, and 38.5% for samples from Wassa-Akropong, Asankragwa, Prestea, Tarkwa, and Bogoso, respectively. Cyanidation can thus be employed to get higher gold recovery in ASGM.

**Keywords:** Small-scale Mining, Tailings, Cyanidation, Gold deportment, Ghana

## 1 Introduction

Over the years, the conventional or traditional method of processing artisanal and small-scale mining (ASGM) gold ores has become dominant in Ghana (Amankwah and Anim-Sackey, 2003; Ofosu *et al*., 2020). ASMG has been recognized as the major job avenue in Ghana, which has contributed significantly to national value addition (Owusu *et al*., 2019). ASGM in Ghana is mostly carried out on gold deposits by using physical processes and simple tools such as a pickaxe, hoe, shovel, head pan, miner's pan, sluice board, dragline, hammer mill, "Changfa" machine, water pump, washing plant, etc. (Massaro and de Theije, 2018). Artisanal miners do not perform any adequate mineralogical or metallurgical analysis before mining the ore, and so they end up leaving a greater percentage of fine and coarse gold into the tailings after gravity concentration (Bansah *et al*., 2018a). Minera-logically, almost 95% of gold can be recovered by simple cyanidation for free milling gold ores, but only (50-85) % of gold can be recovered by simple cyanidation in refractory gold ores (Celeb *et al.*, 2009).

Currently, most small-scale miners use hammer and disc mills for grinding the ore followed by sluicing and panning operations (Figs. 1 and 2). Due to the poor and inefficient processes that are used, it is very difficult to recover about > 90% of the gold. It has been investigated that ASGM operations can recover about 20% to 70% of gold using the primitive level of gravity technology (Veiga *et al.*, 2014). Also, the hammer and disc mills used can grind the ore to a particle size of 80% passing 1 mm and 80% passing 425µm, respectively. These grinding equipment's combine cannot give the optimum gold liberation, since gold particles can be fines in sizes and disseminated in the host rock (Appel and Esbensen, 2019).

The use of inefficient techniques in ASGM is quite common, either to mine the ore or process it, and also there are also issues related to environmental contamination by ASGM (Anticoi *et al.*, 2015; Amedjoe and Gawu, 2013; Saim, 2021). Though ASGM tailings may be considered as an environmental pollutant, they contain considerable amount of unrecovered gold which can also serve as high-grade materials to some medium and large mining companies thus, when processed economically, can generate extra revenue and also increase annual gold production (Bansah *et al.*, 2018b). Therefore, proper characterization of these tailings materials would provide significant information concerning their reprocessing.

**Manuscript received April 30, 2021*
*Revised version accepted December 09, 2021*
https://dx.doi.org/10.4314/gm.v21i2.4

**Fig. 1 Sluicing and Panning Operations of ASGM**

**Fig. 2 Disc and Hammer Used in ASGM**

This paper seeks to assess and characterize the tailings resource from five artisanal and small-scale gold mining operations, and to test the efficiency of gold-cyanidation leaching as a method to recover the ASGM tailings gold from five different sites (Asankragua, Bogoso, Prestea, Wassa-Akropong, and Tarkwa) .

## 2 Resources and Methods Used

### 2.1 Materials and Equipment

Nine tailings samples of about 15-kg each was taken from five small-scale gold mining sites in five towns in the Western Region of Ghana specifically, Wassa-Akropong, Bogoso, Tarkwa, Prestea, and Asankragua (Fig. 3). Roll and cone crushers, Jones riffle sampler, electronic balance, set of screens leaching bottles, pH meter, rollers, lime and, sodium cyanide available at the University of Mines and Technology, Tarkwa, Minerals Engineering Laboratory were used for the experiment

### 2.2 Feed and Tailings Samples Head Grade Determination

The 15-kg sample of tailings from the sites was sun-dried for about 24 hours to remove moisture. The bulk samples were further divided into four representative portions using coning and quartering approach. Samples taken were further split into two representative sub-samples using the Jones riffle sampler until 100-g samples were obtained, bagged, labelled, and sent for fire-assay. The other portion of the sample was further split into two representative sub-samples using the Jones riffle sampler until a 1 kg sample was obtained, bagged, and labelled for size-by-size analysis. The above procedures were repeated for samples from Asankragua, Prestea, Bogoso, and Wassa-Akropong.

### 2.3 Size-by-Size Analysis of Feed and Tailings Samples

1-kg samples which were obtained from the tailings by riffle sampling were subjected to size-by-size analysis to determine which sieve fraction contained most of the gold. 3.35 mm, 1.7 mm, 0.850 mm, 0.425 mm, 0.212 mm, 0.106 mm screen sizes were set for the screening analysis using the 1-kg samples. The oversize and the undersize of each screen were weighed, recorded, and also bagged for fire-assay. The above procedure was done on the samples from all the sites.

### 2.4 Gold Recovery Process from ASGM Tailings Through Cyanidation Leaching

A representative 1-kg sample was taken from the tailings from the Tarkwa site and subjected to direct cyanidation at 40% solids, 1000 ppm cyanide strength at a pH of 11.0 for 48 hours using the bottle roll technique. During this process, the leaching kinetics were monitored and solution samples were taken at 2, 8, 24, and 48 hours to determine the optimum residence time, reagent consumption, and amount of gold in solution. Gold in solution was determined using the Atomic Absorption Spectrometer. Also, the residue or bottle roll leach tailings was washed, dried and 100 g of the dried samples were subjected to fire assay to determine the retained gold in the bottle roll leach tailings. The above procedures were repeated for samples from Asankragua, Prestea, Bogoso, and Wassa-Akropong, respectively. Though the leaching process was not optimised due to fact that the ore chemistry or pulp chemistry of the materials may vary from site to site, the same leaching conditions were used for all the samples from the different sites to demonstrate the leachability of the various tailings materials. The results were plotted graphically and deductions were made on the results obtained and they are discussed in the next section.

## 3 Results and Discussion

This study was carried out to ascertain the resource level in artisanal and small-scale gold mining tailings and optimize extraction through leaching.

Test works were carried out, thus gold deportment analysis, particle size analysis, head assays, and leaching studies.

## 3.1 Size Distribution of Tailings Samples

The particles size distribution in all the tailings materials was determined to identify the 80% passing screen size of the samples. Averagely, the P-80% of all the tailings samples was found to be 1.52 mm (Table 1). This indicates that reprocessing of these materials would require further grinding to achieve significant recovery. This also confirms that ASGM operations do not achieve efficient grinding liberation to recover most of the gold in the smaller size fractions.

**Table 1 P-80% Size Distribution in ASGM Tailings Samples**

| Site | P-80% (mm) |
|---|---|
| Asankragua | 1.797 |
| Wassa-Akropong | 3.210 |
| Tarkwa | 0.380 |
| Prestea | 1.636 |
| Bogoso | 0.578 |
| **Average** | **1.520** |

## 3.2 Head Assays

The head grades of all the tailings samples were determined to know the amount of gold remaining in the samples after processing the ore at the various sites. As shown in Table 2, Tarkwa and Bogoso samples recorded the highest gold grades, with up to 5.97 g/t and 4.12 g/t, respectively, whereas the gold grade in the Wassa-Akropong and Prestea samples was low (0.17 g/t and 0.45, respectively). It is possible the miners were able to recover most of the gold from these samples which led to low gold grade within the tails.

## 3.3 Gold Deportment Analysis

Fig. 4 depicts the gold deportment analysis for Asankragwa tails with a head assay value of 1.84 g/t. From Fig. 4 it can be observed that the particle size range of -1700 + 850 µm had the highest metal unit, with a percent metal distribution of 21.95% which means 21.95% of the gold can be found in the particle size range of -1.7 + 0.85 mm. The -106 µm size, which is of more interest during leaching studies of the tailings also had a significant amount of gold. This indicates that further reprocessing of the tailings can yield more earnings.

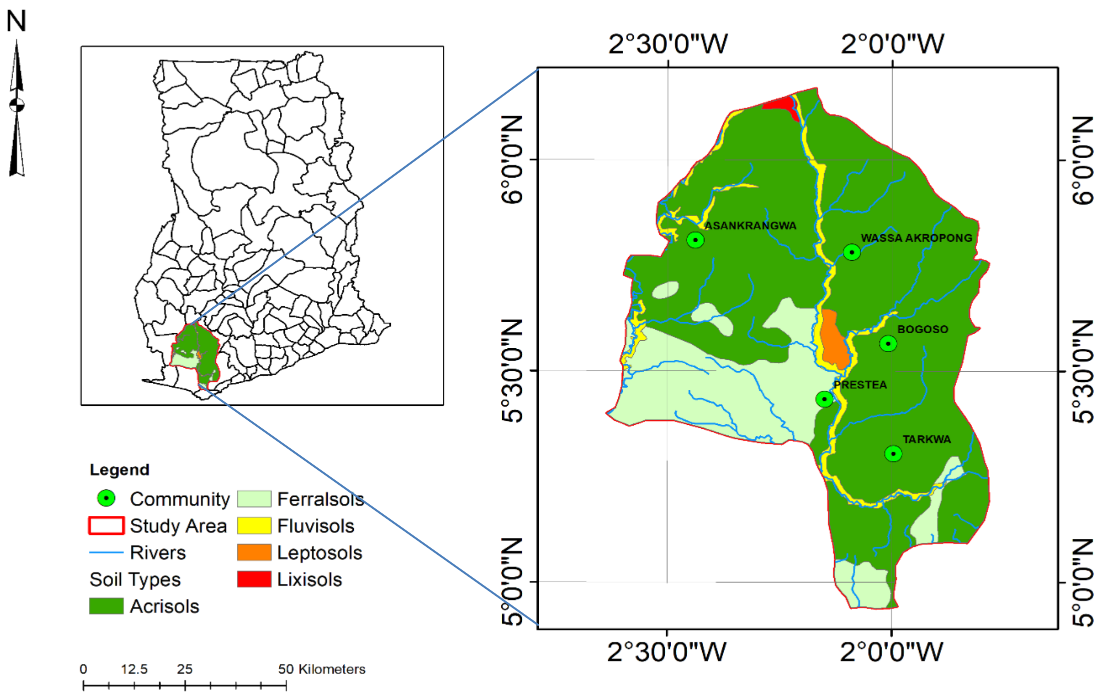


**Fig. 3 Map Showing Sampling Sites**

**Table 2. Head Assays of All the Tailings Samples and the Various Size Grades**

| | ASANKRAGUA | AKROPONG | TARKWA | PRESTEA | BOGOSO |
|---|---|---|---|---|---|
| **size[mm]** | **Assay value g/t** | | | | |
| **+3.35** | 1.47 | 0.15 | 6.19 | 0.50 | 2.77 |
| **-3.35+1.7** | 1.98 | 0.11 | 7.61 | 0.68 | 3.48 |
| **-1.7+0.850** | 2.18 | 0.27 | 6.96 | 0.88 | 2.47 |
| **-0.850+0.425** | 1.79 | 0.08 | 13.37 | 0.53 | 2.24 |
| **-0.425+0.212** | 1.33 | 0.23 | 6.73 | 0.25 | 2.65 |
| **-0.212+0.106** | 1.33 | 1.33 | 6.27 | 0.22 | 4.93 |
| **-0.106+0** | 3.38 | 0.70 | 6.48 | 0.62 | 9.24 |
| **Head Grade** | 1.84 | 0.17 | 5.97 | 0.45 | 4.12 |

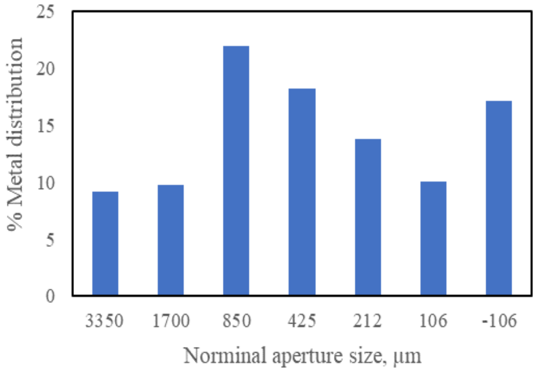


**Fig. 4 Gold Deportment Analysis for Asankragua Tailings**

Figs. 5 and 6 also show the gold deportment analysis of Bogoso and Tarkwa tails with head assay values of 4.12 g/t and 5.97%, respectively. It was observed that the -106 µm had the highest metal unit with a percent metal distribution of 42.03% and 29.71%, respectively. A similar trend was observed. Prestea tails (27%) (Fig. 6), with a head assay value of 0.45 g/t. From Fig. 7, it was observed that the -106 µm had the highest metal unit with a percent metal distribution of 27.04%.

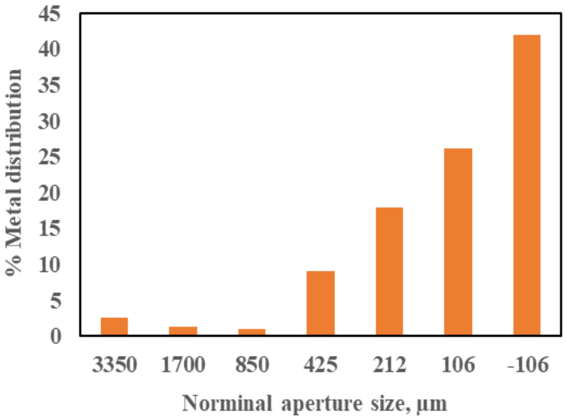


**Fig. 5 Gold Deportment Analysis for Bogoso Tailings**

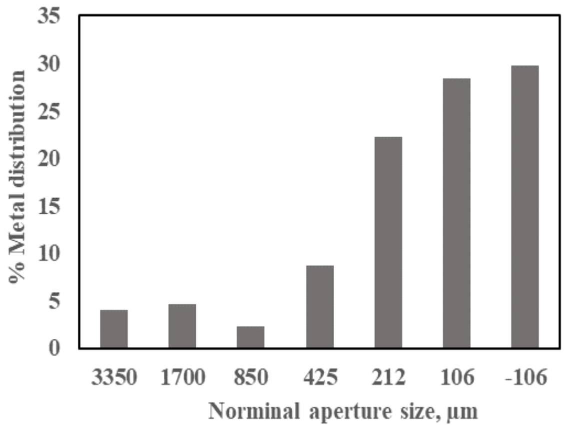


**Fig. 6 Gold Deportment Analysis for Tarkwa Tailings**

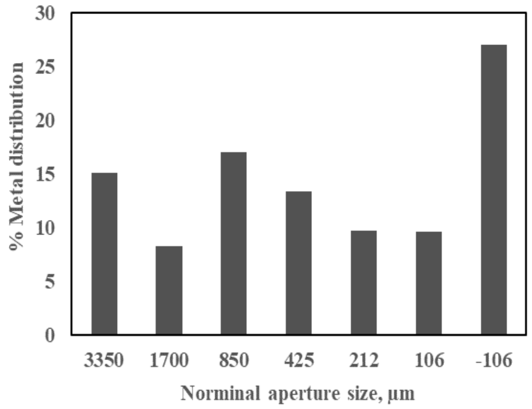


**Fig. 7 Gold Deportment Analysis for Prestea Tailings**

For the tailings samples from Wassa-Akropong, the + 850 µm and +106 µm size fraction had the highest gold content as shown in Fig. 8.

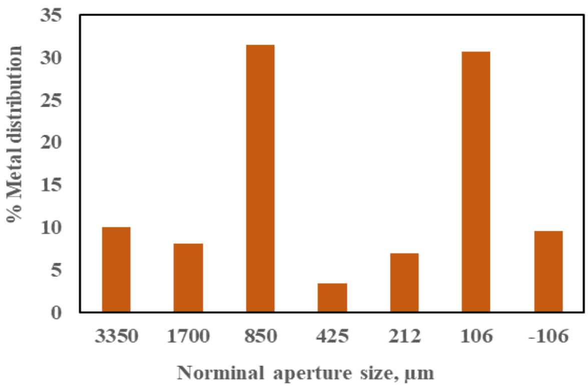


**Fig. 8 Gold Deportment Analysis for Wassa-Akropong Tailings**

### 3.4 Tailings Cyanidation Studies

Bottle roll test was also conducted on the tailings and from the graph (Fig. 9) it was confirmed that recoveries increased with increase in time, which yielded maximum gold recoveries of 66% for Tarkwa, 74% for Prestea, 39% for Bogoso, 72% for Asankragua and 81.5% for Wassa-Akropong. These low recoveries obtained may be partly due to the fact that the gold was not well liberated in the various samples, as most of the gold were found in the smaller size fractions (-106 µm). For instance, from Figs. 5 and 9, it can be seen that the mineral of interest is not well liberated for sample from Bogoso, and this can be attributed to the inefficiency of the grinding process to liberate most of the gold in the smaller size fractions. Moreover, Bogoso ores are known to be refractory (Kesse, 1985). Thus, the low leaching recovery could be attributed to encapsulation and possible refractoriness of the material. In essence, it can be convincing to say that the tailings of these ASGM sites can be leached to recover significant amount of gold (Velásquez-López *et al*., 2011).

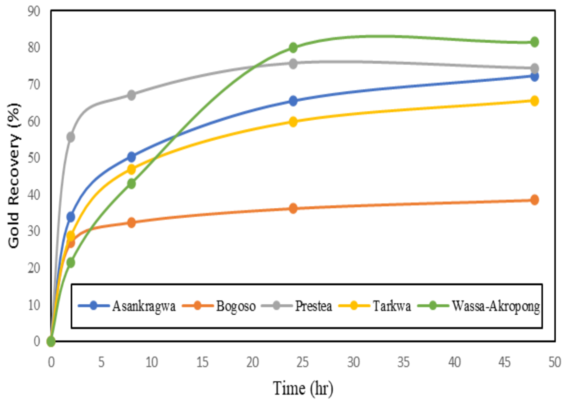


**Fig. 9 Gold Recoveries of All Tailings Samples**

## 4 Conclusions

This study assessed and metallurgically characterised ASGM tailings from five locations in the Western Region of Ghana. Tailings generated in small-scale gold mining operations can serve as a source of ores for mining industries using cyanidation as a source of recovery method. Ironically, these tailings materials can have an average grade of up to 6 g/t. The study from five mining areas shows that all the size fractions tested have significant gold values, especially in the smaller size fractions. Leaching of the tailings materials led to further gold recovery (66.64% averagely); since most of the gold was found in the smaller size fractions, and therefore can be concluded that regrinding and cyanidation can be employed to optimize gold recovery of tailings materials from ASGM operations. It is observed that the grade, highest gold deportment and cyanidation recovery for the tailings samples from Asankragua, Bogoso, Prestea, Wassa-Akropong, and Tarkwa were 1.84 g/t, 4.12 g/t, 0.45g /t, 0.17 g/t, and 5.97 g/t, +850 µm, -106 µm, -106 µm, +850 µm, and -106 µm, and 72%, 39% 74%, 81.5% and 66%, respectively.

The establishment of centralized leaching centres by potential investors and government agencies, where ASGM miners, notably those involved in the Community Mining Programme, would sell their tailings materials for safe metal extraction would be a beneficial alternative for revenue generation. The leaching centres must be monitored by well-trained engineers.

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## Authors

**I. J. Cobbinah** holds a BSc in Minerals Engineering at the University of Mines and Technology, Ghana (2020). He is a Teaching/Research Assistant at Minerals Engineering Department, UMaT. His research interest are extractive metallurgy, small scale mining tailings re-processing and hydrometallurgy. He is a graduate member of the Ghana institute of Engineers (GhiE)

**G. M. K. Gbedemah** holds a BSc (Hons) in Minerals Engineering from the University of Mines and technology. His research interests are hydrometallurgy, microbial technology, ferrous metallurgy and computer application in extractive metallurgy. He is a graduate member of West African Institute of Mining, Metallurgy and Petroleum (WAIMM).

**Z. K. Nurudeen** holds a BSc in Minerals Engineering at the University of Mines and Technology, Tarkwa, Ghana (2020). She is a Teaching/Research Assistant at Minerals Engineering Department (UMaT). Her research interest includes Extractive Metallurgy, Small Scale mining and phyto-nanotechnology. She's a member of Women In Mining, Ghana (WiMGH).

**A. K. Saim** is currently a demonstrator at the Minerals Engineering Department of University of Mines and Technology, Tarkwa, Ghana. His research interests include bionanotechnological applications in minerals extraction and wastewater remediation, machine learning, sustainable small-scale mining, and hydrometallurgy/flotation. He is a graduate member of the West African Institute of Mining, Metallurgy and Petroleum (WAIMM).

**R. K. Amankwah** is a professor of Minerals Engineering from the University of Mines and Technology (UMaT), Tarkwa, Ghana. He holds a PhD degree in Mining Engineering from Queen's University, Canada, and MPhil and BSc in Metallurgical Engineering, both from the Kwame Nkrumah University of Science and Technology, KNUST, Kumasi, Ghana. His research interests include gold beneficiation, water quality management, microwave processing of minerals, small-scale mining, medical geology, microbial mineral recovery and environmental biotechnology. He is a Fellow of the West African Institute of Mining, Metallurgy and Petroleum (WAIMM), a member of the Ghana Institute of Engineers (GhIE) and Society for Mining and Exploration Engineers