# Study on Sumbawa gold recovery using centrifuge

**A D Ferdana[1], H T B M Petrus[1], I M Bendiyasa[1], I D Prijambada[2], F Hamada[3], and T Sachiko[3]**

[1]Advanced Materials and Sustainable Mineral Processing Research Group, Dept. of Chemical Engineering, Universitas Gadjah Mada, Indonesia
[2]Faculty of Agriculture, Universitas Gadjah Mada, Indonesia
[3]Department of Regional studies and Humanities, Faculty of Education and Human Studies Course, The Education and Human Studies, Akita University, Japan

E-mail: bayupetrus@ugm.ac.id

**Abstract.** The Artisanal Small Gold Mining in Sumbawa has been processing gold with mercury (Hg), which poses a serious threat to the mining and global environment. One method of gold processing that does not use mercury is by gravity method. Before processing the ore first performed an analysis of Mineragraphy and analysis of compound with XRD. Mineragraphy results show that gold is associated with chalcopyrite and covelite and is a single particle (native) on size 58.8 m, 117 m up to 294 m. characterization with XRD shows that the Sumbawa Gold Ore is composed of quartz, pyrite, pyroxene, and sericite compounds. Sentrifugation is one of separation equipment of gravity method to increase concentrate based on difference of specific gravity. The optimum concentration result is influenced by several variables, such as water flow rate and particle size. In this present research, the range of flow rate is 5 lpm and 10 lpm, the particle size -100 + 200 mesh and -200 +300 mesh. Gold concentration in concentrate is measured by EDX. The result shows that the optimum condition is obtained at a separation with flow rate 5 lpm and a particle size of -100 + 200 mesh.

## 1. Introduction

Sumbawa is Indonesia's eastern region which rich in mineral resources. Potential of mineral resource Estimated form of gold at 180 thousand $m^3$, Copper at 1.575 million $m^3$, and Limestone at 274.29 million $m^3$, Several studies show that the amount of labor involved in ASGM in Indonesia is between 50,000 and 250,000 people [1].

The amalgamation process is used because of its simple method, The Artisanal Small Gold Mining in Sumbawa is processed with mercury, which poses a serious threat to the mining and global environment [2, 3]. Artisanal Small gold mining uses amalgamation techniques with mercury as its metal catcher. In this practice, mercury is used with excess amount and thus caused significant environmental pollution. But, the process itself is difficult to abolish because of its effectiveness. From local government data of Sumbawa Barat regency there are about 800 kg mercury released per week. Ministry of Environment republic Indonesia has made a plan of action for free mercury gold processing in 2018. This regulation is stemmed from the responsibility to protect the environment while on the other hand also paying attention to the mining rights of locals.

The alternative method for gold processing in artisanal small gold miners is by using the gravity method, the gravity separation method depends on the specific gravity of the mineral, the relative movement of the object, and the magnitude of the frictional force [4]. Separation by gravity technique is the separation of particles from the impurities based on the differences in specific gravity utilizing fluid flow. In the fluid flow there is force resultant between the gravity, friction and buoyancy force which make up terminal velocity. The terminal velocity becomes the base for separation process by gravity separation technique using centrifugation because the magnitude of each mineral's terminal velocity will increase with greater density. The equation of terminal velocity for the laminar flow follows the following Stokes equation.

Not all gold ores can be processed using gravity separation techniques, only native gold and electrum can be processed effectively. Therefore, the characterization of gold ore is crucial to be done before gravity separation process. Table 1 shows the value of the terminals velocity of several compounds of Gold Ore Sumbawa with size -100 mesh.

**Table 1**. Terminals velocity of several compounds of sumbawa gold ore

| Single Partikel | Density (gr/cm3) | Terminal Velocity (cm/s) |
|---|---|---|
| Gold | 19.3 | 0.22 |
| Silicate mineral (SiO2) | 2.65 | 0.02 |
| Sulfide compounds | 7.60 | 0.08 |

## 2. Experimental procedure

There were three main steps in this research, the first was characterization, Analysis of gold characteristic of Sumbawa was done in two stages, the first is X-ray diffraction analysis (XRD) to observe the composition of gold ore from Sumbawa, and the second was making a thin slice of section rock for mineragraphy analysis.

In this study used the optimal conditions in milling process by grinding in a rodmill consisted of 7 pieces of rod with rotational speed of 85 rpm for 120 minutes [5]. Afterward, separation optimization test was done by centrifugation with variable sizes of -100 + 200 mesh and -200 + 300 mesh with response is gold concentration.

## 3. Results and discussion

### *3.1 X-Ray diffraction (XRD) Sumbawa gold ore*

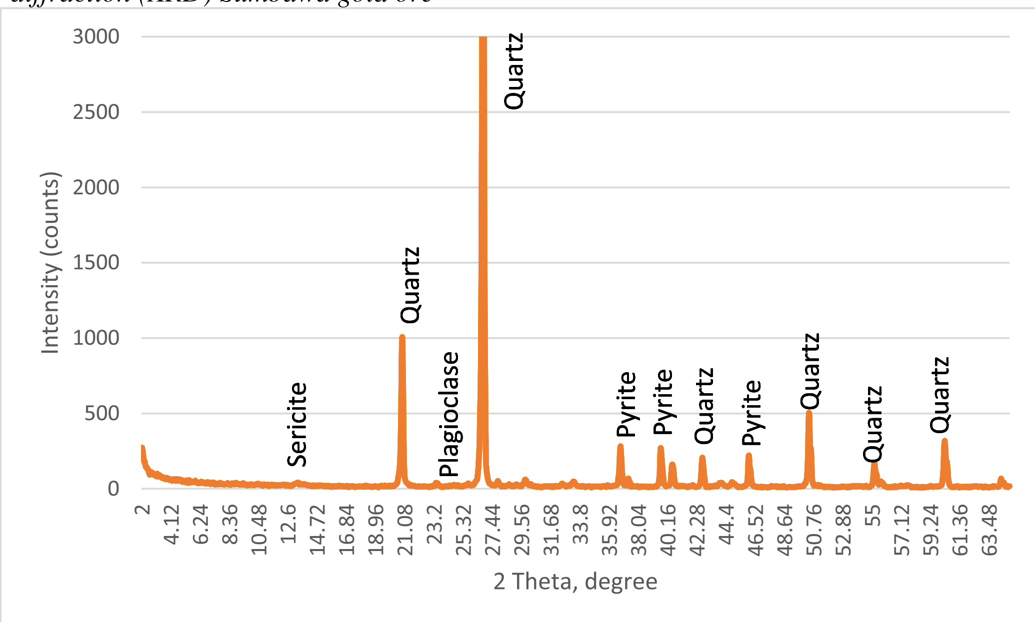


**Figure 1**. XRD Analysis Result

XRD analysis was performed to analyze the compounds of Sumbawa Gold Ore. The XRD gold ore has a mineral composition dominated by quartz, pyrite, sericite, pyroxene. XRD analysis results show that quartz minerals had the largest portion and were dominant in the ore, whereas pyrite and sericite minerals have far less quantities with nearly equal distribution. The analysis outcome shows that gold is mostly associated with quartz. So in gold ore indicated associated with the above minerals.

*3.2 Mineragraphy of gold ore Sumbawa*

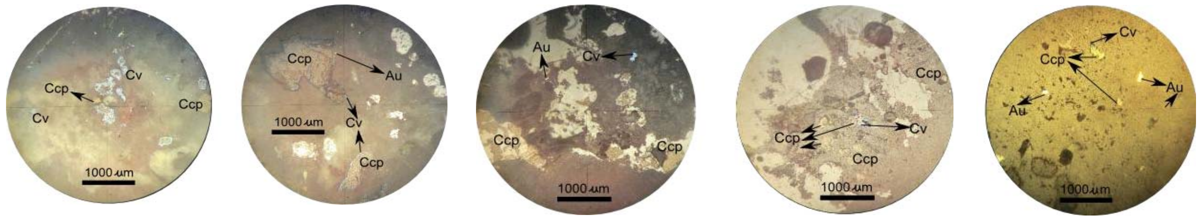


**Figure 2**. Mineragraphy analysis of gold ore sumbawa

Result of Mineragraphy analysis shows that gold ore from Sumbawa contained two main minerals, covelite and chalcopyrite, which are associated with gold with Covellite as the dominant phase. Native gold from this ore was present as individual mineral with shapes ranged from euhedra to subhedra and maximum size of 3000 m. Native gold in this experiment were in smaller sizes with particle sizes of 294 m, 882 m, and 2352.8 m. Ore minerals were bright yellow with shapes ranged from euhedra to subhedra. These minerals can be sized up to 64 m, but more dominant on the size 58.8 m, 117 m up to 294 m [6]. Where: Ccp = chalcopyrite, Cv = covellite, Au = gold. These results serve as a reference for the liberation process using a rod mill

*3.3 Gold liberation*

To get particle size that was smaller and more homogeneous, the particles was subjected through the stages of comminution with grinding. Comminution in the world of mining was instrumental in liberating precious mineral (gold) from the impurities, and the liberation process is done using rodmill. The grinding was done to reach a size of -100 + 200 and -200 + 300 mesh, it was done based on the results of the Mineragraphy of native gold size. After the classification of size was analyzed, the content of gold ore were analyzed with EDXRF.

*3.4 Separation with centrifugation*

In this research, the effectiveness of separation of gold from gangue with centrifugation was tested. The process was influenced by three main variables which are particle size, flow rate, and the response variable in the value of Effectiveness of separation (newton efficiency).

**Table 2**. Experimental data on the increase of gold concentration by centrifugation

| No | Flow rate (Lpm) | Particle size (mm) | Gold concentration (% EDX) | |
|---|---|---|---|---|
| | | | Before centrifugation | After centrifugation |
| 1 | 5 | 0.1115 | 0.218 | 0.595 |
| 2 | 10 | 0.0590 | 0.382 | 0.377 |
| 3 | 5 | 0.0590 | 0.382 | 0.414 |
| 4 | 10 | 0.1115 | 0.218 | 0.409 |

In this process, apart from the increased concentration of gold ore, observations were also made about the decrease of Si content as the main impurity on Sumbawan gold ore. Table 3 shows decrease of Si content on every variable of centrifugation operation.

**Table 3**. Decrease of silica concentrate on centrifugation operations

| No | Flow rate (Lpm) | Particle size (mm) | Gold concentration (% EDX) | |
|---|---|---|---|---|
| | | | Before centrifugation | After centrifugation |
| 1 | 5 | 0.0590 | 48.297 | 9.225 |
| 2 | 10 | 0.0590 | 48.297 | 2.221 |
| 3 | 5 | 0.1115 | 35.068 | 11.893 |
| 4 | 10 | 0.1115 | 35.068 | 3.301 |

With three free variables which were slope of the table, shaking speed, and particle Size with each had only two variations of the upper limit and lower limit. By using minitab 17, the experimental was designed to be divided into eight data points, where each data point was determined to evaluate the value of the response variable which in this case is the separation effectiveness which would determine the gold concentration results in the experiment and in turn determine the value of Newton's efficiency.
Newton's efficiency is a parameter that identifies the effectiveness of a separation process. Newton's efficiency can be calculated based on the following equation:

$$N = Rc-(1-Rfa) \tag{1}$$

Where
N : Newton's efficiency;
Rc : Gold Recovery (%)
Rfa : Impurities (%)

Further recovery of gold minerals from ores in material balance is based on how large the gold mineral content is in the feed, tailings, and concentrates, as shown in the following equation:

$$Rc = \frac{CcWc}{CfWf} = \frac{(Cf-Cfa)Cc}{(Cc-Cfa)Cf} x\ 100\% \tag{2}$$

$$Rfa = \frac{Wfa(1-Cfa)}{Wf(1-C)} = \frac{(Cf-Cc)(1-Cfa)}{(Cfa-Cc)(1-Cf)} x\ 100\% \tag{3}$$

Where :
Wf = weight of feed (kg) (gram);
Wc = weight of gold concentrated (gram);
Wfa = weight of impurities concentrated (gram);
Cf = concentration of gold in feed (%)
Cc = concentration of gold in concentrate (%)
Cfa = concentration of gold in *tailing* (%)

Based on the above equation, the effectiveness of the separation of gold from impurities on each combination of variables is as shown in Table 4:

**Table 4.** Newton's efficiency value on each variable combination

| Flow Rate | Particle Size | Feed Weight | Gold Concentration in Concentrate | newton efficiency |
|---|---|---|---|---|
| | | Wf (gr) | Cc (%) | N |
| 5 | 0.1115 | 34.18 | 0.377 | 94.15686 |
| 10 | 0.0590 | 34.18 | 0.414 | 89.60647 |
| 5 | 0.0590 | 282.58 | 0.409 | 99.46954 |
| 10 | 0.1115 | 282.58 | 0.595 | 97.33463 |

*3.5 Main effect and interaction studies*

The experimental result of the effectiveness of separation is shown by the increase of newton efficiency vs flow rate and particle size as shown in figures 3 and 4.

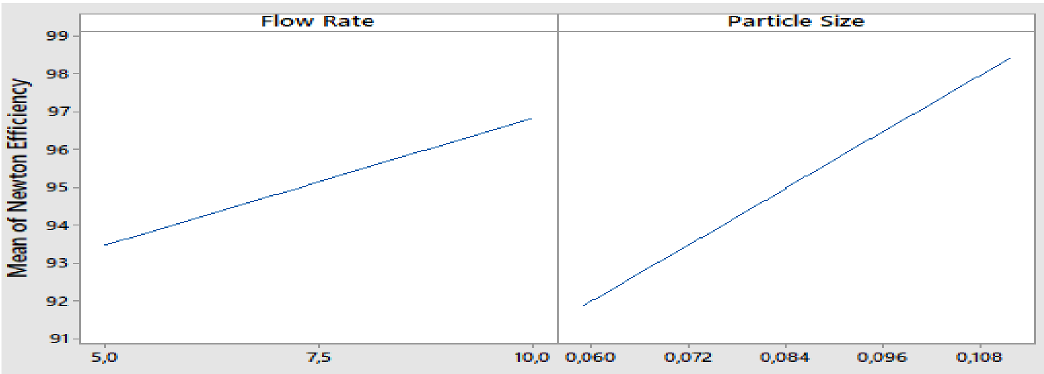


**Figure 3**. Main effect of each single variable

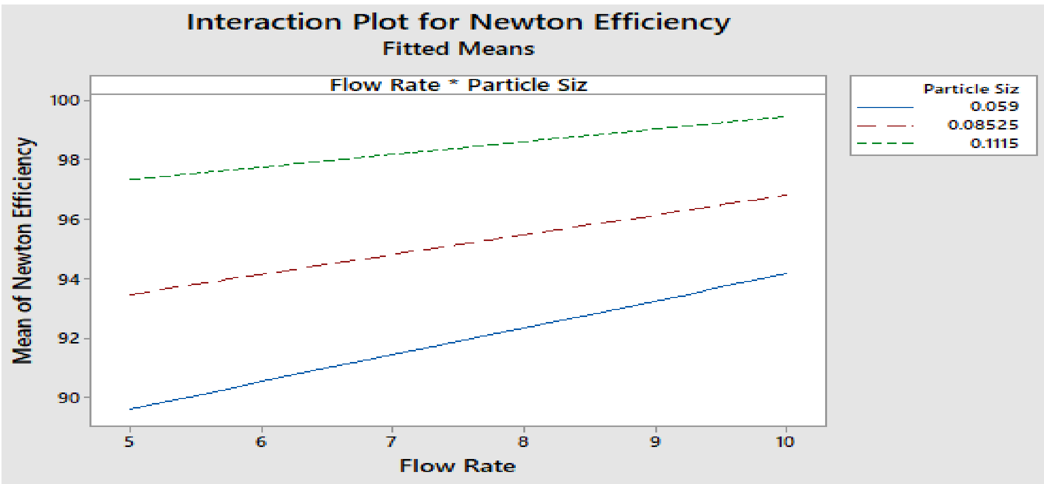


**Figure 4**. Interaction of variables and their effects on Newton efficiency improvements

In this experiment, there were two variable of the flow rate velocity observed which were 5 lpm and 10 lpm. 10 lpm was observed because it was adjacent to the value of the gold terminal velocity that had the highest density on the particle size of -100 + 200 mesh and 5 lpm was observed because it was adjacent to the value of the gold terminal velocity that had the density highest on the particle size of -200 + 300 mesh. For variable size, also two variables were observed which were -100 + 200 and -200 + 300 because they were in the range of gold size which was free from impurities based on mineragraphy analysis.

From figure 3 and 4, it is apparent that the effect of the flow rate on the effectiveness of the separation shows with higher flow rate, the greater the effectiveness of the separation, and with larger particle size, the effectiveness also increase. This is shown in the effectiveness of the variable flow rate of 5 lpm with 0.059 particle size compared to the effectiveness at flow rate of 10 lpm with particle size of 0.1115 in which the value of newton efficiency are 99.46954 and 97,33463 respectively. Because it is the basis of separation with the size of the velocity terminal of each particle. Comparison of the effectiveness gold separation with different amount gold concentration in each variable is shown in Figure 5:

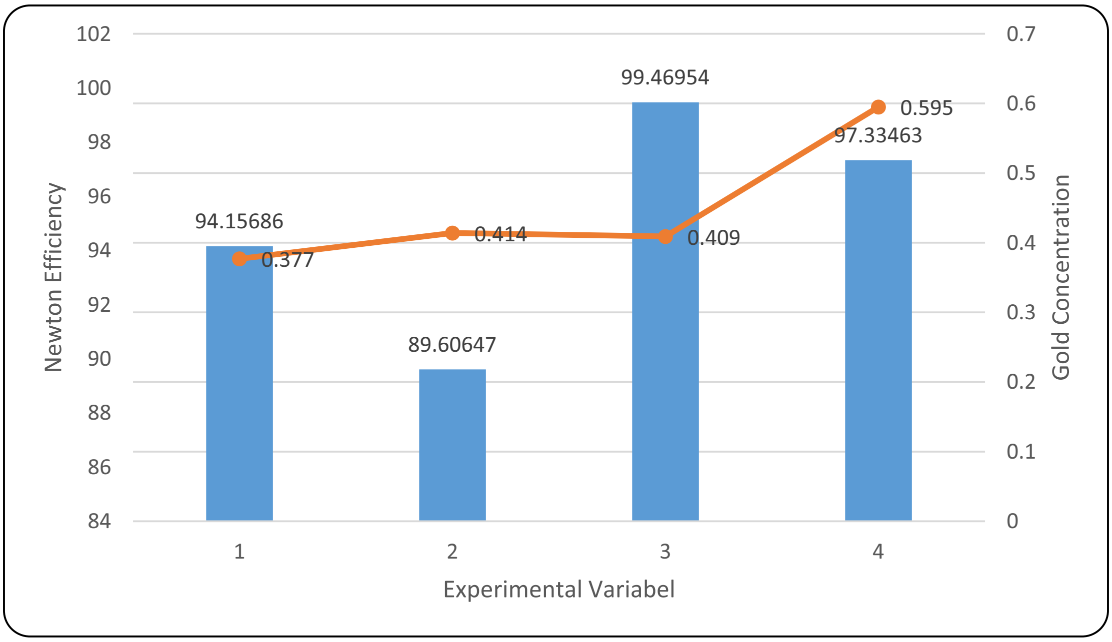


**Figure 5**. Newton efficiency and gold concentration of each variables

Figure 5 shows that the best separation effectiveness which indicated by the best newton efficiency values is obtained in the experiment with variables of flow rate of 5 lpm and particle size of 0.059 mm with Newton Efficiency value of 99. 46954%. If viewed from the amount of effectiveness of separation with the same particle size, Experiment with flowrate of 10 lpm resulted in Newton Efficiency of 89.60647%. These results differ greatly, as this result also shows that in determining the flow rate in separation by centrifugation, it must correspond to the speed of the nearest terminal velocity of the heaviest impurities so that the impurities will be carried away with the flow and only gold will be left behind. These result were also shown at the experiment with the particle size of 0.1115 mm, at a flow rate of 5 lpm, effectiveness of separation of 94.15686 were obtained while at flowrate 10 lpm the effectiveness was 97.33463. This shows that in the separation by gravity technique using centrifugation the main variable to watch for the success of the separation is the value of the terminals velocity needed for each particle to be separated.

## 4. Conclusion

Based on the results of the mineragraphy analysis, the gold was associated with chalcopyrite, and covellite. Native gold had size between 58.8 m, 117 m to 294 m. Based on the results of XRD analysis, gold ore from Sumbawa composed of quartz, pyrite, piroksen, and serisit. The optimal conditions in the gold ore separation using centrifugation were between flow rate 5 lpm with particle size 0.059 mm and flow rate 10 Lpm with particle size 0.1115 lpm.

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