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CENTER FOR ETHIO- MINES DEVELOPMENT

Study on the efficiency of gravity beneficiation method on gold-bearing ores from Lega Dambi and Sakkoro deposits by using Laboratory Scale Shaking Table.

This Project was Submitted to Department of Ethio-Mines Development of Addis Ababa University as Partial Fulfilment of the requirements for the Degree of Master of project in Mineral Engineering.

By Megersa Teku Hunde

Advisor: Prof. Alberto Velazquez Del Rosario

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By: Megersa Teku

Approval board:

Dr. Berhanu Assefa:		31/10/2023
Director, Center for Ethio-mines Development	Signature	Date
Prof. Alberto Velazquez Del Rosario		24-10-2023
Advisor	Signature	Date
Examiner: Dr. Zekarias Gebreyesus		26/10/2023
	Signature	Date

Declaration

I hereby declare that this project is my original work and has not been presented for a degree in any other university, and that all sources of material used for the project have been duly acknowledged.

Megersa Teku ______________ 24-10-2023

(Student) Signature Date

Approved by

Prof. Alberto Velazquez Del Rosario ______________ 24-10-2023

(Advisor) Signature Date

Abstract.

This study focuses on the investigation of the efficiency of a gravity separation as pre - concentration for a gold samples taken from Laga dambi openpit, and Sakkorro underground gold mine by using Shaking table concentrator. The bench-scale test work was performed on samples taken from Midroc Lega Dembi gold mine, Ethiopia to provide information on the gravity recoverable gold (GRG) content and the optimum size range for gravity concentration, and gold distribution by using a shaking table concentrator, to determine the efficiency of gravity method as a pre-concentrate by using shaking table. The GRG test was performed at entire sample passing (P_{100}) through 2000 μm, 710 μm, and 500 μm sieve aperture at first, second and third sages respectively. Fire assay analysis was undertaken to determine the content of gold element in the shaking table products.The results of GRG test have indicated that 17.11% , 19.73% , and 27.44 % of the GRG from the ground ore were recovered into a concentrate at first, second, and third stages respectively. Totally about 64.29 % GRG was recovered into concentrate from three-stage tests for the gold ore samples taken from Lega Dembi and Sakorro gold mine. The International standards (I.S) sieves having the following narrowing sieve sizes: 2000μm, 140 μm,1000 μm,710 μm, 500 μm, 355 μm, 250 μm, 150 μm, 75 μm, and pan were selected to conduct size analysis. The cumulative gold distribution obtained from the three stage concentrates size analysis was indicated that an approximately 85%, 69%, and 53% of the available gold was contained at the average size of 112 μm, 200 μm, and 302 μm respectively. However the cumulative GRG distribution shown that only 47.38%, 24.23 %, and 12.96 % of the GRG was recovered into concentrates of shaking table at the mean size of 112 μm, 200 μm, and 302 μm respectively. These indicated that the gravity separation was not effective to pre-concentrate the Lega Dembi, and Sakorro gold ore at relative coarse particle sizes by using shaking table concentrator.

Keywords: Gravity recoverable gold, pre-concentration, gravity separation, shaking table concentration

Acknologement.

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I love and appreciate all of you so very much!!

Acronyms

Au	Gold.
AGEP	Adola Gold Exploration Project.
CIL	Carbon in Leach.
CIP	Carbon in Pulp.
EMRDC	Ethiopian Mineral Resources Development Corporation.
g	gram.
GRG	Gravity Recoverable Gold.
g/t	gram per tone.
I.S	International standards.
µm	Micrometer.
Km	Kilometer.
m	meter.
%	percent.
$\geq$	Greater than or equal.
P_{100}	Entire sample passing through a given sieve aperture size.
P_{80}	Eighty percent passing through a given sieve aperture size.

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1. Introduction.

1.1. Background

Gravity separation is commonly utilized in gold processing facilities as the main method of recovery (most frequently for placer gold ores) or as a step before other process steps like flotation and cyanidation (Laplante.A, 2005). The high specific gravity of gold (19.3 g/cm3 for pure gold) makes it possible to separate it from gangue minerals within the ore that have lower densities (such as calcite, quartz, and spalerite, which have densities of 2.71; 2.65; and 4, respectively). Gravity separation generally has some benefits over flotation and leaching, including low capital and operating costs, comparatively little environmental impact (material released into the environment is relatively less harmful), and comparatively simple operations (Laplante and Spiller, 2002; Falconer, 2003; Wills and Finch, 2016).

Recently in most modern gold processing plants aqueous cyanidation processes are used to leach fine gold particles (Marsden and House, 2006a), while gravity concentration methods usually separate coarse gold particles before cyanidation (Ernawati et al.,2018; Laplante and Gray,2005; Egan et al., 2016; Ofori-Sarpong et al.,2019). Gravity concentration is particularly useful when there is significant coarse gold (>200 μm) present in the ores because coarse gold particles take the longest time to leach during atmospheric cyanide leaching.

Therefore, integrating gravity concentration before cyanidation, especially when the ore contains coarse gold particles, makes shorter leaching retention time due to the removal of free coarse values, reduces the reagent consumption, lower carbon costs, and consequently improves the overall gold recovery (Laplante and Grey, 2005; Vincent, 1997; Siame et al., 2014). The financial benefits of the gravity element of the circuit can frequently be quite strong in circuits that include gravity and cyanidation. (Laplante 2005) states that the gain for every 10% increase in gravity-based gold recovery typically equates to an extra 0.2-1.0% of total gold recovery.

In gravity concentration, the desired material is separated from a mixture of particles of various sizes, densities and shapes utilising gravitational or centrifugal forces (for centrifugal concentrators) (Ghaffari and Farzanegan, 2017). There were different kinds of gravity recovery equipment used, in the gold processing plant, some of the most common gravity separation equipment include jigging concentrator (Richards and Jones.,2004; Laplante and Grey, 2005), shaking tables (Manser et el., 1991), spiral concentrators (Palmer and Vadeikis, 2010), and centrifugal gravity separators such as Knelson and Falcon (Palmer and Vadeikis, 2010; Laplante and Grey, 2005; Chen et al., 2017; Zhao et al., 2016).

Shaking table separation techniques have generally shown to be more effective than other gravity concentrators due to their wide range of applications, as well as the pre-concentration is relatively easy to run and has a simple flow sheet (Wills and Finch, 2016). Shaking tables are useful for processing material with a size between 3 mm and 20 m. According to earlier study (Mitchell et al., 1997; Wang and Poling, 1983), it is possible to recover up to 90% of gold that has a size larger than 40 μm, compared to typically only 20% of gold that is between 20 and 40 μm in size. A properly operating shaking table is one of the most efficient units in mineral processing even though the shaking table is low unit capacity it still finds significant application in various sectors of the industry (Burt, 1987).

The general operating principle of the shaking tables concentrator was reported in the earlier study (Falconer, 2003; Wills and Finch, 2016). Slurry feed is introduced at the feed box and contains around 25% solids by weight. Wash water is provided from the upslope side through a perforated pipe. The idea behind separation is the flow of particles in a slurry across an inclined table that effectively oscillates back and forth at right angles to the slope. Along with the shaking motion, the wash water and gravitational forces enable the shaking table to stratify materials both horizontally and vertically across the table surface according to their specific gravity (SG) and size. The dense particles that are entrained within the slurry sink to the deck, travel along the riffles, and ultimately discharge as the concentrate product. The slurry's light, coarse particles were suspended in the wash water, spread out more horizontally, passed directly over the riffles, and finally discharged as tailings. In contrast, an intermediate product (usually an unlibrated dense particle) is discharged as a middlings between the concentrate and the tailings.

Lega Dembi and Sakorro gold mine in Ethiopia is the largest gold producer in the country. The project is located some 500 km from Addis Ababa, in the Oromia regional state of southern Ethiopia. The Adola Gold Exploration Project (AGEP) of the Ethiopian Mineral Resources Development Corporation (EMRDC) conducted an exploration campaign in the late 1970s and discovered primary gold occurrences, including the Lega Dembi deposit. According to a previous study (Billay et al., 1997), the structural layout, lithological assemblages, and gold mineralization style in Lega Dembi are almost identical to lode-gold deposits commonly found in Archaean granite-greenstone terranes.

Previous Study by (James Strongman, 2007) was conducted on four samples taken from the gold mine at Lega dembi, Midroc in order to determine mineralogical, and Midroc gold distribution. Investigations revealed that sulphide mineralization, including pyrrhotite, pyrite, galena, and chalcopyrite, predominated in the gold sample ore. Additionally, it includes varying amounts of coarsely freed Scheelite. Midroc gold distribution on four samples indicated that in the three of the samples gold occurs as > 200 µm liberated grains, however within one of these samples, the gold is finer (< 100 µm) and locked to gangue silicates and sulphides. This revealed that the possibility of a pre-concentrate coarse gold particle size greater than 200 µm prior to cyanidation treatment by using gravity method. In this investigation, samples were taken from the active mine area for lab-scale testing to determine the effectiveness of gravity separation as a pretreatment step utilising the shaking table.

1.2. Statement of Problem

Due to its high efficiency and relatively low cost, traditionally gold cyanidation is a common practice in most gold processing plants. Currently Lega Dembi gold processing plant utilizes direct cyanidation leaching to extract gold from whole ore. In these processes, the pre-treatment was limited to fine grinding that closed with hydro-cyclone classification, and only the cyclone overflow material was forwarded for leaching while the underflow was milled further. The results of earlier research on the behaviour of gold in grinding circuits, however, showed that cyclones are particularly powerful at retaining excess gravity-recoverable gold in the milling circuit, leading huge circulating quantities of gold (Banisi et al., 1991a). Prior to moving on to downstream processing like cyanidation or flotation, gold particles larger than 75 µm will typically circulate 50–100 times in a grinding circuit, according to (Laplante and Grey 2005).

Another problem associated with the use of cyanide is environmental concerns due to its toxicity, especially in areas of concentrated population and bountiful water resources. During gold leaching, cyanide generates a series of health related accident's, and significant environmental problems at various gold mines around the world.

According to most previous research (La Brooy et et al., 1994; Marsden and House, 2006a), cyanidation is quite effective at processing more easily extractable/free-milling gold. The amount of gold recovered, however, is some what influenced by the leach rate and grind fineness (La Brooy et al. 1994). Previous data on leaching kinetics of gold (Alp et al, 2003) showed that excessive duration of leaching times were required to achieve high gold extraction (>90%). 96–97% of the gold in Lega dembi was recovered by cyanide leaching over leaching periods of 42–43 hours [Personal communications]. This relatively long leaching times (residence time) needed to achieve large recoveries by cyanidation are maybe due to the presence of coarse gold within the ores. Consequently, to address these issues, a laboratory test known as the GRG test is necessary to be carried out on a sample of gold ore utilizing lab-scale shaking table in order to investigate the effectiveness of the gravity beneficiation method on the pre-concentration of the target ore.

1.3. Objectives

1.3.1. General Objective.

The general objective of this study was to investigate the effectiveness of the gravity beneficiation method on gold-bearing ores from Lega Dambi in the Oromia region of southern Ethiopia, by using Laboratory Scale Shaking Table.

1.3.2. Specific Objective.

- To determine the Gravity-Recoverable Gold (GRG) content of the Lega Dembi gold ore sample using a laboratory shaking table.
- To determine the Gravity-Recoverable Gold (GRG) size distributions within a gold ore sample by using a size analysis and assey by fraction.
- To identify the gold (Au) size distribution within a gold ore sample by using a size analysis and assey by fraction.
- To determine the optimum size range for GRG recovery of the ore sample from GRG recovery vs particle sizes graph.

1.4. Scope

This study was designed specifically to evaluate the effectiveness of the gravity beneficiation technique for the Lega Dembi gold processing plant, by predicting the gravity recoverable gold content and the optimum size range for GRG recovery of a representative gold ore sample, and determining the size distribution GRG and their corresponding gold distribution based on size analysis and fire assay results from a sequential stage GRG test. A combination of earlier scientific and GRG test methodologies were employed to conduct this test on samples of gold ore.

1.5. Significances

The significance of this study is recovering the GRG easily by gravity concentrator before cyanidation within the grinding circuits with little effort and at a lower cost than cyanidation. As a result, the retrofitting of a gravity technique utilizing a shaking table before cyanidation within the grinding circuit hopefully enables the company: to reduce the cyanidation circuit's reaction time, hence reduce gold loss to tails and spillage, by recovering coarse GRG that led to increased cyanide reaction times, high undissolved gold losses, and lower gold recoveries ; to reduce the amount of gold that circulates during grinding and hydro cyclone classification, by recovering the coarse gold that led to reduce the efficiency of downstream processing units, to minimize the amount of cyanide by recovering the part of gold by gravity processing, and gradually enable the company to improve its overall recovery.

2. Literature Reviews

This literature review, highlight different topics such as: types of gold bearing ores, main methods of gold ore processing, and gravity-recoverable-gold (GRG), a review some of the most common gravity devices in primary gold processing and a detailed description of the shaking table concentrator.

2.1. Types of gold bearing ores.

Due to the numerous variables that can affect the recovery of gold, different classification systems for ore containing gold are currently published; however, the general idea is the same regardless of the classification system used (Habashi, 2005; Karimi et al., 2010; Miller, Wan, and Diaz, 2005; Vaughan, 2004; Zhou and Cabri, 2004). However, according to the methods needed for gold recovery and mineral processing, (La Brooyet et al., 1994) commonly divide gold ores into three broad types (free-milling, complicated, and refractory ores) (Figure.1).

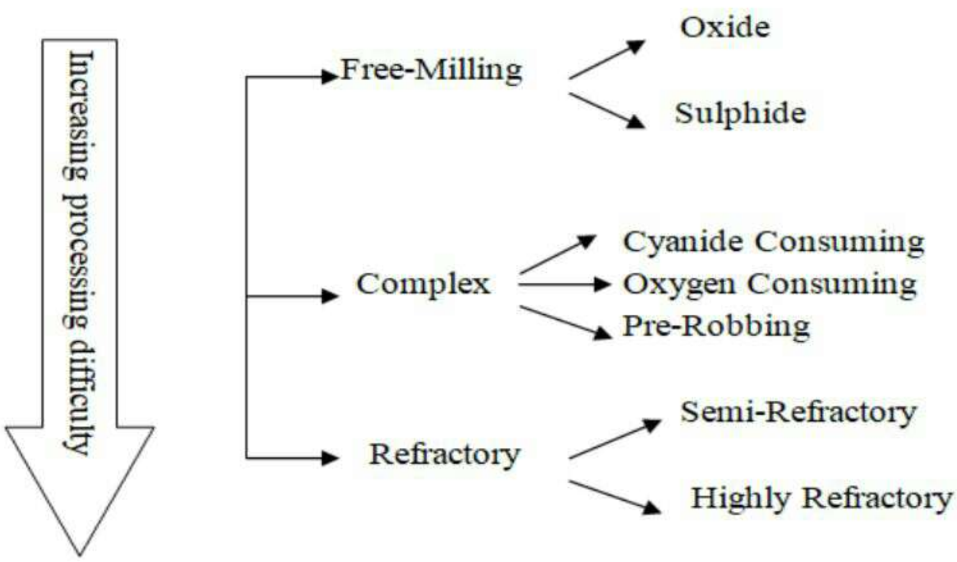

Figure 1. Route used for processing gold (source La Brooyet el., 1994).

2.1.1. Free-milling

Free, or free-milling, gold is commonly defined as gold that exists as discrete particles rather than gold that exists on a molecular level inside the host mineral matrix. Placer, quartz vein gold ores, and oxidised ores are the most common types. Under typical cyanide treatment conditions, free-milling ores are those that recover over 90% of the gold (La Brooyet et al., 1994).

Free-milling sulphide ores contain both coarse and fine-grained gold particles, which can be recovered by whole-ore cyanidation or a combination of flotation, gravity concentration, and cyanidation. Complex ores, on the other hand, are those that only yield a commercially viable gold recovery with the use of much higher chemical additions (such as cyanide, oxygen, and carbon).

2.1.2. Refractory

In refractory ores, sulphide minerals, especially pyrite and arsenopyrite, are closely associated to gold. Direct leaching of the concentrate results in poor gold extractions because the cyanide lixiviant cannot access the gold locked inside the refractory host. A pre-oxidation procedure is frequently necessary to oxidise the base metal sulphides and expose the gold particles for later leaching. To ensure excellent recoveries from refractory minerals, it is frequently crucial to carry out a pre-treatment such as ultrafine milling, roasting, biological oxidation, and pressure oxidation. Pre-treatments like ultrafine milling, roasting, biological oxidation, and pressure oxidation are typically necessary to ensure high recoveries from refractory ores.

2.1.3. Complex

Complex ores are those from which sufficient gold recoveries may be obtained, but only under adjusted or more exhausting leaching conditions.Preg-robbing and reactive minerals are the two subcategories of complex ores. Preg-robbing ores contain material capable of absorbing cyanide during leaching. It has been suggested by (Goodall et al., 2005; Miller et al., 2005; Vaughan, 2004) that clays have a poor potential for cyanide absorption. But cyanide is frequently absorbed by carbonaceous minerals, especially organic and elemental carbon. Complex gold ores may contain reactive minerals that, in side reactions, consume the leaching agents and lower the amount of cyanide and/or oxygen that can be used to leach the gold. Pyrhotite, copper minerals (apart from chalcopyrite) such as chalcocite, malachite, azurite, and cuprite, and the majority of base metal minerals are examples of these minerals (Karimi et al., 2010; Aylmore and Mum, 2001). These ores can be treated by employing larger reagent concentrations than would be necessary for normal cyanidation.

2.2. Main Methods of Gold Ore Processing.

Numerous unit methods exist for gold recovery, and Figure 2 depicts the primary processing alternatives for free-milling gold production in relation to the previously identified and categorized major gold categories. Through the years, gravity, cyanidation, and flotation have been the most often used unit processes for recovering gold.

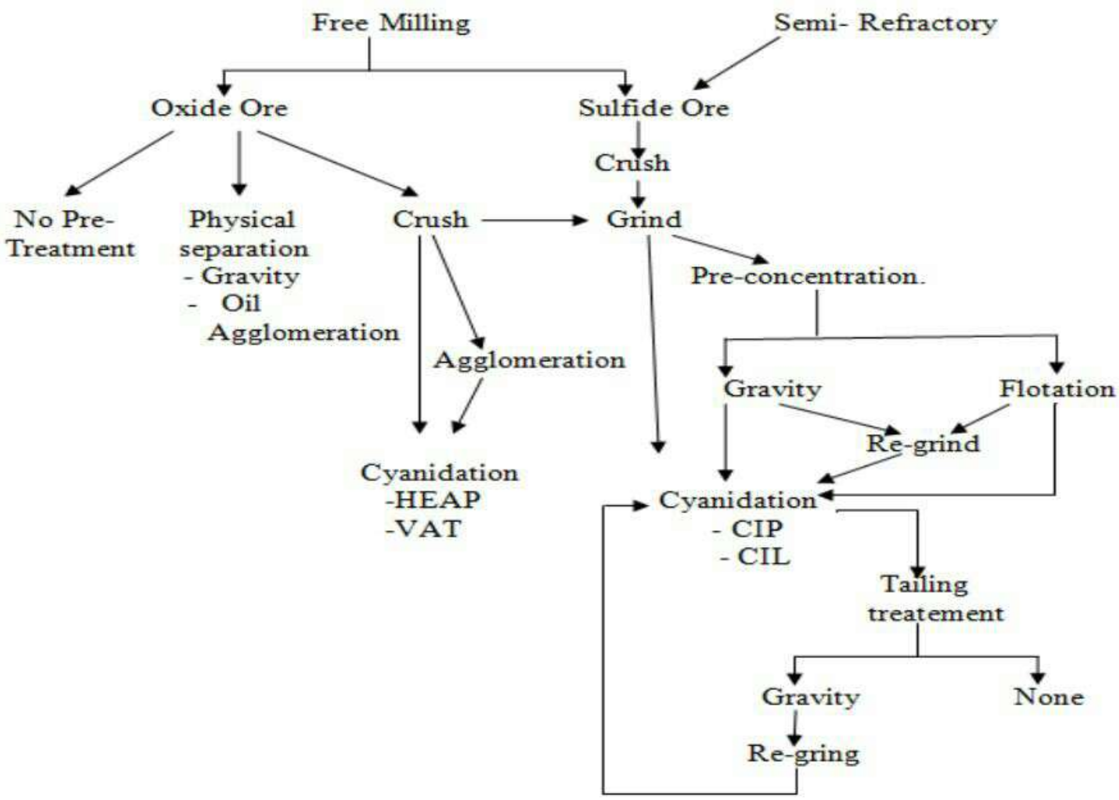

Figure 2. Gold processing options for free milling and semi-refractory ores (La Brooy et el., 1994)

The primary focus of this investigation is the gravity concentration of gold.The other gold processing techniques, such as flotation, amalgamation, and cyanidation, must be briefly detailed in order to be comprehensive in the gold recovery hierarchy; however, they must not be mentioned after this section.

2.2.1. Gold Amalgamation.

Gold amlgamation is an ancient process that involves the alloying of the gold particles with metallic mercury to form amalgam and then the separation of the gold from the mercury by heating in retorts until the mercury is gets distilled out. According to (Taggart, 1945) mercury diffuses into gold, first $AuHg_2$, then Au_2Hg, and lastly Au_3Hg was produced. Gravity concentration and amalgamation of gold in milling circuits were retained after the introduction of the cyanide extraction process and yielded between 15 and 60 % of the total production (Burt. 1984).

Amalgam is the simplest and most inexpensive gold extraction process, which produces free pure gold with a maximum recoveries of up to 30% (Santos 2004). But this process is effective in fully or partially liberated gold in particle sizes of 0.07 mm - 1.5 mm (Hylander et el. 2007). Amalgamation was eventually eliminated because of health –considerations however it is still used extensively by artesian mines in third-world countries and small mines, due to its simplicity.

2.2.2. Flotation.

The flotation process separates valuable minerals or metals from gangue material based on surface property differences, with an emphasis being placed on physical and chemical variables for gold recovery (Laplant A, 2005a). Gold has a close relationship with sulphides, either in the form of barren and hydrophobic sulphides or as fine unliberated grains (solid solutions or inclusions). According to (Forrest et al., 2001), pyrite, arsenopyrite, and to a lesser extent pyrrhotite are the three sulphides that are most usually found to contain gold. Free gold particles greater than 200 μm are usually readily recoverable by gravity separation but are too large for effective flotation recovery. While "normal" flotation can be used very successfully to recover free gold at smaller particle sizes (< 200 μm), the selectivity for free gold flotation rapidly declines at finer particle sizes (<20 μm) (Marsden and House, 2006). Because gold is so ductile, it is usually not readily reduced to fine particle sizes and can therefore build up in grinding circuits due to its high density (Woodcock et al., 2007). In the process, the gold surface can be damaged and pick up surface coatings, which may reduce its floatability. As a consequence, it is usually recommended to have a gravity and/or flash flotation circuit before flotation where coarse native gold is known to be present in the feed (Woodcock et al., 2007).

2.2.3. Gold Cyanidation.

Gold cyanidation has been the most important method of gold extraction from gold ores since its first commercial application in 1889. The oxidation of gold in an aqueous cyanide solution results in the formation of a highly soluble aurocyanide complex, which can then be used to separate the gold from the gangue. Equation (1) describes the general reaction flow (Marsden and House, 2006):

$2Au + 8NaCN + O_2 + 2H_2O = 4AuNa(CN)_2 + 4NaOH$ ……………………………..…….eq (1)

The process of cyanidation is typically used to extract free-milling gold with a fine grind as a pretreatment to make the gold accessible to cyanide, not necessarily fully liberated, however, the cyanide leaching rate and the final gold recovery vary depending on the grinding fineness (La Brooyet et al., 1994). Typical gold recovery efficiency for cyanidation range from 95 to 99% (Marsden and Fuerstenau,1993). Gold is dissolved using cyanide solution and the resulting complex, $Au(CN)_2$, can be removed from the solution by various methods (Deschenes.G., 1986);

-Zinc dust cementation (Merril–Crowe Process)

Gold can be recovered from cyanide solutions using cementation (precipitation), which uses zinc dust as catalyst for reduction and precipitates gold using the general procedure described in equation two below.

$2NaAu(CN)_2 + Zn \rightarrow Na_2Zn(CN)_4 + 2Au$. ………………………………………………eq (2)

This method called the “Merril–Crowe Process” has been used worldwide since the 1890s. If present, silver is also precipitated similarly. For the treatment of high-grade gold solutions or solutions with a lot of silver, this method is chosen.

- Adsorption on activated carbon.

Gold can also be recovered from cyanide solutions by adsorption on activated carbon. Because of its technical and economic advantages, the “Carbon-In-Pulp” (CIP) process has been established as the standard method for the recovery of gold from cyanide solutions. Before the pulp is in touch with the carbon, there may normally be one or two leaching stages since gold recovery with carbon is typically optimal between pure CIP and CIL (Nicol et al.,1984). Following leaching, activated carbon is combined and stirred with the pulp in a succession of typically 5-7 tanks. In contrast to CIL, where pulp and activated carbon come into contact in a counter flow, CIP involves the pulp and the carbon coming into contact in a countercurrent flow. Finally the pulp and the loaded carbon are separated by sieving.

2.2.4. Gravity

Gravity concentration is widely used for the recovery of free gold and gold associated with heavier minerals (e.g., many sulfide and titanium minerals). Since the beginning of mineral processing, has served as the primary method of recovery in gold processing plants ever since the advent of mineral processing (most typically for placer gold ores) or as a step before other processing stepslike flotation and cyanidation (Laplante. A, 2005). Different types of gravity concentrations such as Jiggs, spiral, shaking table, and centrifugal concentrators such as Nelson and Falcon concentrators have been reported to separate both coarse and fines gold as pre-concentration methods for gold recovery by cyanidation (Wills and Napier-Munn, 2006).

Gravity recovery has virtually disappeared for security reasons and due to the increased efficiency of carbon circuits (Laplante. 1995). Gravity recovery however is still extensively used and has experienced a resurgence in popularity due to the advent of the Knelson Concentrator (Hart and Hill. 1995).Recently, the recovery of gold using gravity methods has gained attention because of low cost, environmentally friendly operations, and recent developments of centrifugal gravity concentrators such as Nelson and Falcon, have enabled the recovery of free gold down to about 20 µm in size, and occasionally gold particles of 10 µm diameter and below were recovered.

2.3. Typical Gravity Recovery Devices.

In general, gravity separation processes have progressed from devices that use the earth's gravitational field, such as sluices, jigging, and spirals, to batch-enhanced (centrifugal) gravity concentrators, like nelson and falcon, and currently to continuous enhanced gravity concentrators. According to (Wills and Finch, 2016), all gravity concentration techniques generate movement between the gold and host rock particles to separate the heavier from the lighter particles of material. (McGrath et al., 2015; Jena et al., 2017) claim that the size and shape characterizations of gold particles have a direct bearing on the efficiency of gravity separation machinery.

2.3.1. Knelson Concentrator

According to (Sampaio and Tavares,2005), centrifugal concentrators were mostly utilized to recover fine gold, platinum group minerals, and chromite are currently recovered using Knelson Concentrators (Laplante & Grey 2005). Various gravity devices for gold recovery have been replaced in recent years because to the KC's exceptional performance throughout a wide size range (Zhang et al., 2022; Guernsey et al., 2003; Laplante and Grey, 2005; Chen et al., 2017; Zhao et al., 2016). The literature (Knelson & Jones, 1994; Coulter & Subasinghe, 2005) provides a thorough explanation of the general operating concept of the Knelson Concentrator.

2.3.2. Spirals.

Spirals are commonly employed for GRG and gold-carriers recovery because of the high density and low abundance of gold in the ore (typical gold ore grades are less than 5 g/t). For instance, a series of rougher (creating gold pre-concentrates) and cleaner (removing impurities from gold concentrates) spirals at the New Celebration gold mine in Western Australia often produce gold recoveries of 70 to 80% (Martins et al, 1993). Spirals can also be used to recover fine gold that is flat-free (up to 85% recovery rate) and gold that is finer than 37 microns (up to 50% recovery rate), according to Feree (1993). Although spiral plants require a large number of units to achieve considerable throughputs, spirals also have relatively cheap running costs (Smit et al., 2012).

2.3.3. Jiggs.

Jigs that use gravity concentration can operate across a very broad size range. Jigs can be used from 100 m to 25 mm, however they perform best between +200 m and 10 mm (Nigel and Georges, 2014). Jigs and other continuous gravity machines can handle varying grades and flow rates, are relatively simple to operate, and are very inexpensive to run. Despite being well-known and easy to use, jigs may have ineffective partition curves.

2.3.4. Shaking tables.

Shaking tables are gravity concentration devices that consist of a riffled flat surface, inclined slightly from the horizontal, shaken with a differential movement in the direction of the axis of tilt and washed at right angles to the direction of motion by a stream of water.

For processing a variety of minerals and coal with a range of particle sizes from 15 mm to 10-15 μm, shaking tables are one of the most conventional but effective tools (Wills and Napier-Munn, 2006; Manser et al., 1991). Shaking tables are devices for gravity concentration that have flat surfaces that have been riffled, tilted slightly from horizontal, shaken with differential motion in the direction of the tilt, and then washed by a stream of water at a right angle to the motion. The literature (Falconer, 2003; Wills and Finch, 2016) provides a full description of the shaking table concentrator's overall operation. Wash water is fed from the upslope side through a perforated pipe. The shaking action and the wash water cause the slurry feed to spread out over the table through a distribution box along part of the upper edge (table 4). A short arm with a motor attached shakes the table throughout its length, perpendicular to the water flow, and parallel to the distribution of riffles.

The dense particles that are entrained in the water descend to the deck, travel along the riffles, and discharge into the concentrate as a result of the horizontal shaking, gravitational forces, and riffles arrangement. However, the lighter and intermediate particles that were suspended in the river were spread out more horizontally and passed directly over the riffles before falling to the ground and ending up in the tailings or middle.

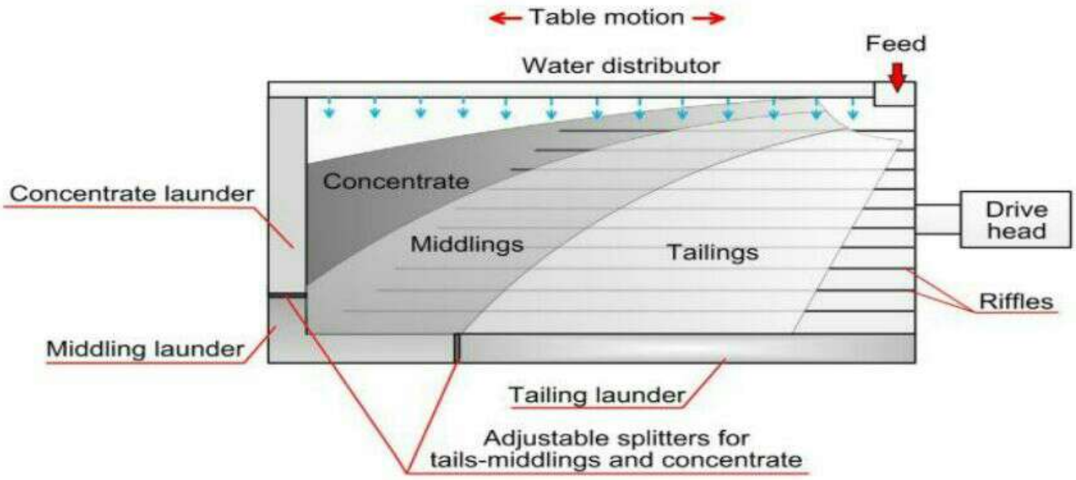

Figure 3. A concentration table showing the particle paths of high density (concentrate), intermediate density (middlings), and low density (tailings) particles.

2.3.4.1. Main Variable in Shaking table

According to (Sivamohan and Forssberg ,1985; Falconer,2003; Wills and Finch, 2016), and others, some of the key factors influencing the separation process in a shaking table are mentioned and discussed below.

- Deck Angle,
- Wash water flow rate,
- Particle size.
- Particle shape.
- Riffle height , and
- Length and Frequency of stroke.

Deck Angle. The deck of the shaking table, that's generally rectangular and has an adjustable slope of around 0° to 6° higher in some circumstances, as mentioned by (Mitchell et al., 1997), must be modified depending on the type of ore and its grain size (Sampaio and Tavares, 2005). More ore may be treated when the table's lateral slope is at higher angles. Finer and lighter materials can be retained on the table at lower frontal slope angles.

Wash water flow rate. To help with solids movement, maintain low solids density, avoid "dry spots," and clean concentrate, wash water is introduced along the top of the table in addition to the water in the feed pulp. In accordance with the type of feed material, this ranges from a few litres to approximately 21-100 L / minutes.

Particle size. In table separations, particle size is crucial; the separation efficiency declines as the range of sizes in a table feed expands. A table feed will not be cleaned effectively if it contains a variety of particle sizes. The middlings generated could not be "true middlings," that is, trapped particles of linked mineral and gangue. They would be pointlessly reground if these particles were returned to the grinding circuit together with the actual middlings. According to Mitchell et al. (1997), shaking tables are useful for processing material that is between 3 mm and 15 μm in size. Up to 90% of gold coarser than 40 μm can be retrieved, according to previous studies deposits (Mitchell et al., 1997; Wang and Poling, 1983), but often only 20% of gold between 20μ and 40 μm can be.

Feed rate and density. Feed rate and density separation may prove less effective (below a maximum of approximately 2 tph per full size table and density typically 40% solids, depending on the kind and particle size of the feed). While the amount of water used in the feed pulp varies, the typical feed dilution for ore tables is 20% -25% solids by weight, while the recommended amount for coal tables is 33% to 40% solids by weight.

Particle shape. The shape of the gold grain also affects the process of gold processing using the gravity shaking table method. According to (Maharaj et al. 2012), the gravity separation states became more challenging as particle granularity decreased. Flaky gold is a type of gold grain with a bigger surface area that can be carried on the tailings and hydrophobic gold has a surface that prefers the air, which lowers its density and causes it to fall as tailings.

Additionally, (Ofori-Sarpong, and Amankwah, 2011) noted that different shapes of particles experienced various resistance forces in the medium as well as various particle motion velocities. (Gupta and Yan, 2006) discovered that the gold particles had a tendency to have flatter shapes than the sulphide particles.

Riffle height. The height of the riffles varies depending on the ore's grain size, but is typically between 3 and 5 mm. For fine feeds, a low riffle height will be preferable, and vice versa.

Length and Frequency of stroke. The length of the table's horizontal movement has a significant impact on how much gold is recovered. For gold with fine grain sizes, rapid speed is advantageous (Wills and Finch, 2016).

Splitter positions. The weight taken to concentrate will be determined by the splitters' position on the concentrate laundry machine.

2.4. Gravity Recoverable Gold

Gravity-recoverable gold (GRG), as described by (Laplante and Gray, 2005; Staunton, 2011) is a measure of how much gold can be recovered using gravity techniques as batch centrifugal concentrators or shaking tables. It is based on liberated gold or high-grade composite gold particles. Additionally, gold in the form of gold-sulfide mineral particles may be recovered using low-force gravity separation in continuous gravity recovery devices. Due to the apparent particle density being lower than that of free gold, gold carriers gold particles linked with sulfides typically do not report to the concentrate in GRG recovery. For normal reporting to the GRG concentrate stream, partially liberated gold must have a high SG (above 14) (Laplante and Grey, 2005; Staunton, 2011).

The majority of plants are concerned in recovering GRG because it represents a fraction of the incoming gold that can be easily recovered by gravity with little effort and at a lower cost than either flotation or cyanidation. Sometimes it can be difficult to recover part of the GRG by techniques like cyanidation (which lengthens the leach duration for GRG) or flotation. For further processing, it may be advantageous to recover coarse free gold and some complex gold sulphide minerals using a jig or batch centrifugal concentratoter such as knelson consentrator, as they may make cyanidation more challenging (Laplante and Grey, 2005). As they may make cyanidation more difficult, it may be desirable to recover coarse free gold and some complicated gold sulphide minerals for further processing using a jig or batch centrifugal concentrator like the Kelson concentrator (Laplante and Grey, 2005). As a result of classification, the majority of coarse and intermediate particles will cycle through the mill, so it's crucial to not overemphasize a slow kinetic rate of large gold grains in leaching (Laplante and Staunton, 2003).

GRG typically recycles via a grinding loop prior to going through downstream processes like cyanidation or flotation, which can result in significant gold circulation loads building up, because of its high density and extremely mellow nature. According to (Laplante and Grey ,2005), gold particles larger than 75 μm will typically pass through 50–100 times in a grinding circuit before reporting to the next processing units. The more time this gold spends in circulation, the more likely it is that it will interact with grinding medium, grinding equipment, and gangue minerals in a way that might decrease its downstream recovery. In order to lessen these interactions, adding a gravity circuit to handle the gold-circulating load's bleed stream is typically an efficient strategy.

The engineering evaluations and the design of the gold ore dressing process both heavily rely on the forecast of gold recovery. Three methods to assess an ore's susceptibility to gravity concentration were identified by (Laplante and Xiao., 2001). Commissioning a sizable pilot plant is the most thorough and expensive strategy. The system needs some time and effort to equilibrate, even though the outcomes might be the most trustworthy in the long run. Second, for a moderate expense, a running plant can choose to conduct in-plant testing by modifying the current circuit. Finally, for a low cost, running concentrators may choose to commission the laboratory GRG test program.

2.5. Main findings from Literature Review.

According to the literature review the most common gold processing methods are cyanidation, flotation, and gravity methods. Generally plants are interested in recovering GRG because it represents a fraction of the incoming gold that can be recovered easily by gravity with litle effort and at a lower cost than either flotation or cyanidation. By removing this easily recoverable gold from the circuit early, the rest of the circuit can be focused on the gold that is harder to recover. Also some of the GRG is sometimes difficult to recover via processes such as cyanidation (increased leach time for GRG) or flotation. Coarse free gold and some complex gold sulfide minerals can complicate cyanidation.

GRG tends to recycled numerous times through a grinding loop before it is of proper size and liberation; this can lead to the build up of major circulating loads of gold. The longer this gold circulates the more likely it is to interact with grinding media, grinding equipment, gangue minerals and dissolved species in a manner that may lower its downstream recovery, therefore the inclusion of a gravity circuit to treat a bleed stream of the gold circulating load is often an effective action to minimize these interactions.

It is important to select the correct tool for any pre-concentration application. Of all the methods available, gravity separation is commonly deployed (Smit et al, 2012). Kelson concentrator, Jigs, spirals, and shaking table are the most options as the grind size reduces. Jigs may function over a very large size range in gravity concentration, which is most frequently employed to recover coarse gold prior to cyanidation. Jigs and other continuous gravity machines can handle varying grades and flow rates, are relatively simple to operate, and are very inexpensive to run. Despite being well-known and easy to use, jigs may have ineffective partition curves. Spirals also have a very low operating cost; however spiral plants require multiple units to achieve high throughputs (Smit et al, 2012).

3. Materials and Methods.

3.1. Materials.

About a 20 kg representative sample of gold-bearing ores used in this study was collected from two different mining sites: Lega Dembi openpit and Sakorro underground mine, located in the Oromia regional state of southern Ethiopia. A representative sample was collected to permit a GRG test by using a lab-sale shaking table concentrator. To ensure a homogeneous feed for subsequent GRG tests by using shaking table separation, the samples collected from Lega Dembi openpit and Sakorro underground mines were blended before crushing

3.2. Sample Preparation.

A 20 kg sample of gold ore, with an initial top size of > 20 mm was primarily subjected to crushing, and ore sample was crushed P80 below 18 mm (P80 finer than 18 mm) in laboratory jaw crusher (MGOLD-LD20-0554) Figure 4.

Figure 4.Laboratory jaw crusher.

Fine crushing is the preferable comminution technique, according to (Gray, and Hughes, 2007; Ofori-Sarpog, and Amankwah, 2011), as the resulting gold or gold-sulfide particles are better suited for gravity separation. The crushed product of the gold ore sample was finely crushed and/or ground in three consecutive steps and recovery to prepare the feed for gravity separation. The initial stage involved crushing the entire sample to a particle size of less than 2000 μm (P100-2000 μm).

This fine crushing was conducted at Midroc Gold Mine Plc's laboratory quality control division by using a laboratory-scale boid crusher (MGOLD-LD20-0555) (Figure 5).

Figure 5. Laboratory scale boid crusher.

Once the feed material is P100–2000 μm, it is fed onto the shaking table, which uses gravity separation to carry out the P100–2000 μm separation. The first stage's tailings were next ground for 20 minutes in a laboratory ball mill to produce a particle size distribution with a P100 passing the 710 μm (P100 -710 μm), before it was processed on the second stage shaking table. The second stage's tailings were ground to a P100 below 500 μm in a laboratory ball mill for 30 minutes and processed again.

3.3. Separation via shaking table.

In this study, the GRG test was carried out utilizing a shaking table concentrator to ascertain the GRG content, the optimum size range for gravity concentration, and distribution of gold in a gold ore samples. The GRG test was conducted at Midroc Gold Mine Plc, Metallurgical Laboratory division by using a laboratory-scale shaking table Figure 6. According to a previous study (Grayson 2007), a shaking table concentrator may be able to recover > 90% of the gold from ores with gold grain sizes of 3 mm to 70 m. To see the efficiency of gravity concentration as pre-concentration, a lab-scale shaking table was used, and the test followed (Laplante and Spiller's 2002) procedure.

All GRG tests at the succeeding three phases were conducted following the guidelines outlined in (Freelander, 2015) utilizing a shaking table with a 4 - 5° deck angle, a ground ore slurry that was 25% solid, and 15 L/min wash water. However, slurry was manually added into the shaking table constantly and continuously. The shaking table concentrator produce concentrate, middling and tailing products but in this study middling and tailing were considered as a tailing product.

Figure 6. Laboratory-scale Shaking table.

The test consisted of three sequential steps involving gravity concentration followed by regrinding of the middling and tailings prior to the next stage of gravity concentration, and the general flow sheet for the three-stage gravity tests is shown in Fig. 7. Each stage of grinding was aimed at improving gold liberation.

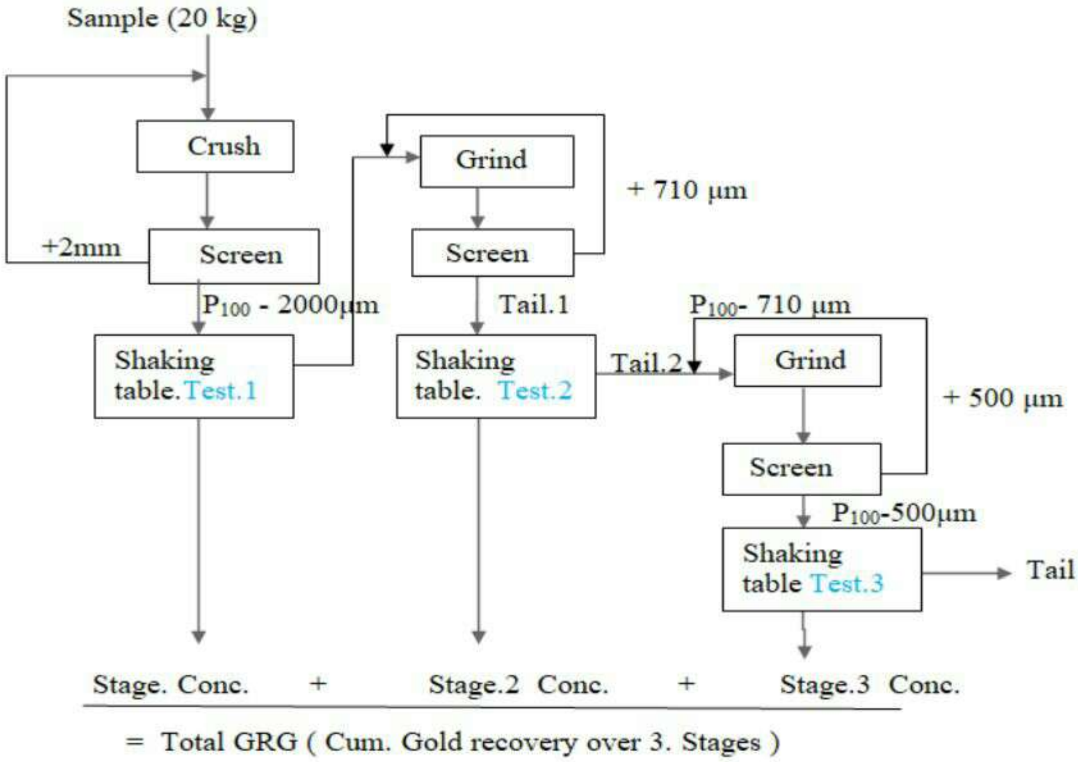

Figure 7. The GRG test procedures use a bench-scale shaking table gravity method.

The recovery of each test was collected, filtered by using filter press, and dried by using dry oven to constant weight in well labelled trays.

3.4. Size Analysis and Au assey.

Following the successive stages of GRG test, size analysis and Au assay by using fire assay analysis was conducted to determine the gold distribution, and GRG distribution in the feed, concentrate, and tailing materials. Size analysis was conducted by utilizing International standard (I.S) sieve test ,having the following narrowing sieve sizes: 2000μm, 140 μm,1000 μm,710 μm, 500 μm, 355 μm, 250 μm, 150 μm, 75 μm, and pan. Each particle size fractions obtained from batch sieving operations were mixed thoroughly and passed through a riffling sampler, until sets of 300- 400g samples were obtained for Fire assays.

4. Result and discussion.

4.1. Particle Size Distribution.

The particle size distributions of the feed samples at three successive stages were shown in figure 8. As shown in figure.8 the P100 passing of the initial size distribution of the ground gold ore sample for the first, second, and third-stage tests were 2000 µm, 710 µm, and 500 µm respectively.

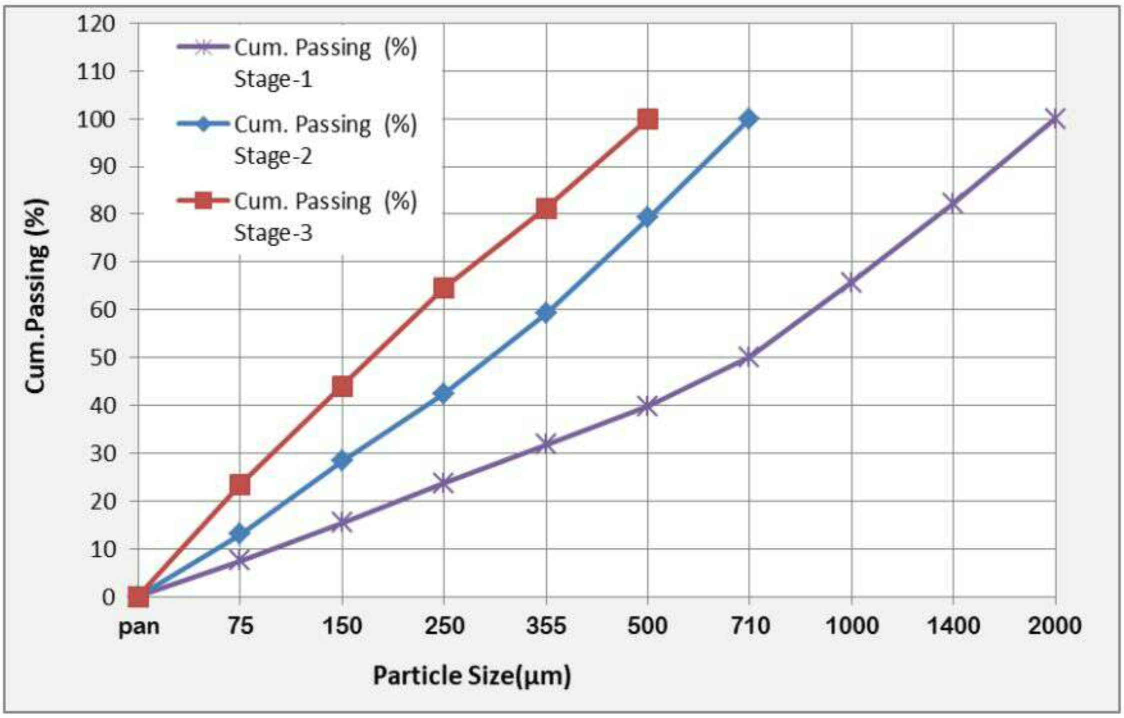

Figure 8. The particle size distributions of the feed samples at three successive stages.

4.2. Gold Assay by Fractions.

From the fire assay, the average feed gold grade was found to be 5.65 g/t. The results of gold assay by fractions on samples of concentrates, and tailing obtained from shaking table products at three successive stages were shown in tables 2,3, and 4 respectively. The highest fractional gold grade of concentrates obtained at three successive stages was found in the similar particle size fraction (-150+75 µm).

Table 1. Gold assay results by fractions for the first stage GRG test using Fire assay analysis

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Particle Size(µm)	Concentrate		Tail	
	Sample code	Assay (g/t Au)	Sample code	Assay(g/t Au)
(-2000+1400)	GT1C1-1	1.91	GT1T1-1	4.51
(-1400 + 1000)	GT1C1-2	3.91	GT1T1-2	4.25
(-1000+710)	GT1C1-3	16.13	GT1T1-3	0.02
(-710+5000	GT1C1-4	24.22	GT1T1-4	5.81
(-500+355)	GT1C1-5	48.87	GT1T1-5	6.54
(-355 +250)	GT1C1-6	66.91	GT1T1-6	5.96
(-250+150)	GT1C1-7	117.22	GT1T1-7	5.26
(-150+75)	GT1C1-8	272.77	GT1T1-8	3.87
(-75)	GT1C1-9	183.91	GT1T1-9	4.18

Table 2. Gold assay results by fractions for the second stage GRG test using Fire assay analysis.

Particle Size(µm)	Concentrate		Tailing	
	Sample code	Assay (g/t Au)	Sample code	Assay (g/t Au)
(-710+50)	GT2C2-1	4.11	GT2T2-1	3.47
(-500+355)	GT2C2-2	14.41	GT2T2-2	3.51
(-355 +250)	GT2C2-3	29.3	GT2T2-3	4.35
(-250+150)	GT2C2-4	75	GT2T2-4	4.22
(-150+75)	GT2C2-5	233.03	GT2T2-5	3.06
(-75)	GT2C2-6	154.35	GT2T2-6	3.92

Table 3. Gold assay results by fractions for the third stage GRG test using Fire assay analysis.

Particle Size(µm)	Concentrate		Tailing	
	Sample code	Assay (g/t Au)	Sample code	Assay (g/t A)
(-500+355)	GT3C3-1	9.13	GT3T3-1	3.01
(_355 +250)	GT3C3-2	13.94	GT3T3-2	3.59
(-250+150)	GT3C3-3	34.02	GT3T3-3	2.4
(-150+75)	GT3C3-4	88.27	GT3T3-4	1.48
(-75)	GT3C3-5	64.85	GT3T3-5	1.6

4.3. Fractional Gravity Recoverable Gold (GRG) Recovery and Au size Distribution.

The GRG tests in this study involved three steps of recovery on the ground ore to assess the gold content of the ore that could be recovered by gravity utilizing a shaking table. Tables 5, 6, and 7 illustrate, respectively, the fractional recovery of gold particles in each size range in concentrates, and tailing of a shaking table at successive three phases based on the results of the Fire assay analysis. According to (Wills and Napier-Munn, 2006b), recovery can be calculated by applying the following equation.

$$R = \frac{Cc}{Ff} \times 100 \quad \text{eq (3)}$$

where: R= recovery of valuable metal,

C = the mass of the concentrate,

c= the concentration of metal in concentrate,

F = the mass of feed sample and

f = concentration of metal in feed sample.

For example Applying Equation 3 for the shaking table products of size - 2000µm +1400 µm (Table 1), the gold recovery is calculated by substituting each parameter in the equation for recovery as follows:

$$R = \frac{157.4 \; x \; 1.91}{3540 \; x \; 4.39} \times 100 = 1.93 \; \%$$

The same formula was used to get the gold recoveries for the remaining size fractions shown in table 5, 6, and 7.

Table 4.Calculated fractional GRG recovery, and gold distribution of the first stage shaking table concentrator.

Particle Size(μm)	Concentrate				Tailing			Feed			
	mass (g)	Au(g/t)	Fractional Rec.(%)	Unit Recovery(%)	Mass (g)	Au(g/t)	Fractional Rec. (%)	mass(g)	Au (g/t)	Unit	Dist'n(%)
(-2000+1400)	157.4	1.91	1.93	0.26	3382.6	4.51	98.07	3540	4.39	15550	13.76
(-1400 + 1000)	127.8	3.91	3.55	0.44	3202.2	4.25	96.45	3330	4.23	14100	12.48
(-1000+710)	50.2	16.13	6.045	0.72	3065.8	0.02	93.95	3116	4.3	13400	11.86
(-710+500)	47.9	24.22	9.07	1.03	2000.1	5.81	90.93	2048	6.24	12790	11.32
(-500+355)	30.9	48.87	12.8	1.34	1573.1	6.54	87.2	1604	7.36	11800	10.44
(-355 +250)	27.2	66.912	16.21	1.61	1578.8	5.96	83.79	1606	6.99	11230	9.94
(-250+150)	27.3	117.22	26.89	2.83	1652.7	5.26	73.11	1680	7.08	11900	10.53
(-150+75)	21.3	272.77	49.24	5.14	1548.7	3.87	50.76	1570	7.52	11800	10.44
(-75)	23	183.91	40.56	3.74	1483	4.18	59.44	1506	6.93	10430	9.23
Total	513	37.7	17.11	17.11	19487	4.81	82.88	20000	5.65	113000	100

The fractional GRG recovery and mass of the first stage concentrate is presented in figure 9. In this first stage of GRG test, the fractional recovery with the highest percentage was observed at a size range of (-50+75 μm) whereas the highest mas of concentrate found in the finer size range. This higher mass with lower GRG recovery at larger particle size range may implied the coarser light material and unliberated coarser (i.e. GRG) material was recovered whereas lower mass of concentrate with higher GRG recovery at finer particle size range may implied in the finer size range only liberated dense material (i.e. GRG) was recovered into concentrate.

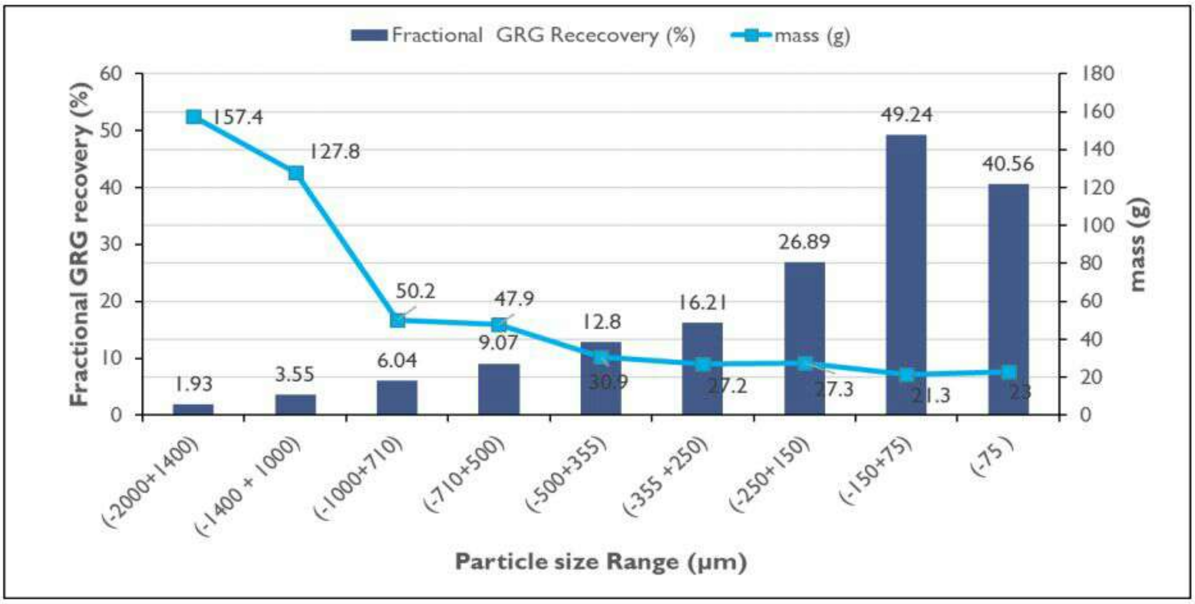

Figure 9. Fractional GRG recovery and mass into the first concentrate.

The distribution of gold and the calculated fractional GRG recovery for the first stage shaking table concentrator can be seen in Figure 10. The size distribution of gold was found to be nearly identical for the coarse and fine fractions. However the unit GRG recovery higher at fine particle size range than coarser particle size range this may implied finer particle size range may liberated that is an appropriate to recover via shaking table.

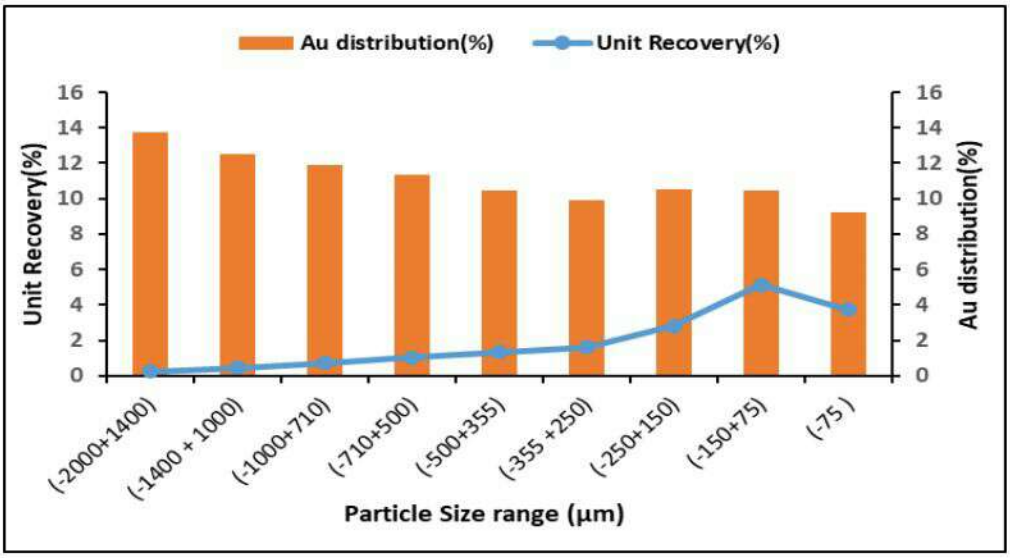

Figure 10. The distribution of gold and the calculated fractional GRG recovery for the second stage shaking table concentrator

Table 5. Calculated fractional GRG recovery, and gold distribution of the second stage GRG test using shaking table.

Particle Size(μm)	CONCENTRATE				TAILING			FEED			
	mass (g)	Au(g/t)	Fractional Rec. (%)	Unit recovery (%)	Mass (g)	Au(g/t)	Fract Rec. (%)	mass(g)	Au (g/t)	Unit	Au Distribution (%)
(-710+5000	109.6	4.11	3.94	0.63	3155.77	3.47	96.06	3265.37	3.49	11410	15.98
(-500+355)	54.12	14.41	6.65	1.09	3117.99	3.51	93.35	3172.11	3.7	11730	16.43
(-355 +250)	44.02	29.3	10.24	1.81	2597.67	4.35	89.76	2641.69	4.77	12600	17.65
(-250+150)	39.2	75	24.22	4.12	2178.15	4.22	75.78	2217.35	5.47	12140	17
(-150+75)	21.8	233.03	40.97	7.12	2393.58	3.06	59.03	2415.38	5.13	12400	17.37
Pan	23	154.35	31.92	4.97	2032.11	3.72	68.075	2055.11	5.41	11120	15.57
Total	291.74	48.3	19.73	19.74	15475.26	3.7	80.27	15767	4.53	71400	100

The second stage GRG test was run using the second stage's tailing, which was ground to P100 - 710 μm. The fractional gold recovery of the second stage are presented in row 4 of Table 3, and Figure 11. At (-150 +75 μm) which is identical to the first stage, the highest fractional recovery of about 40.97% was attained.

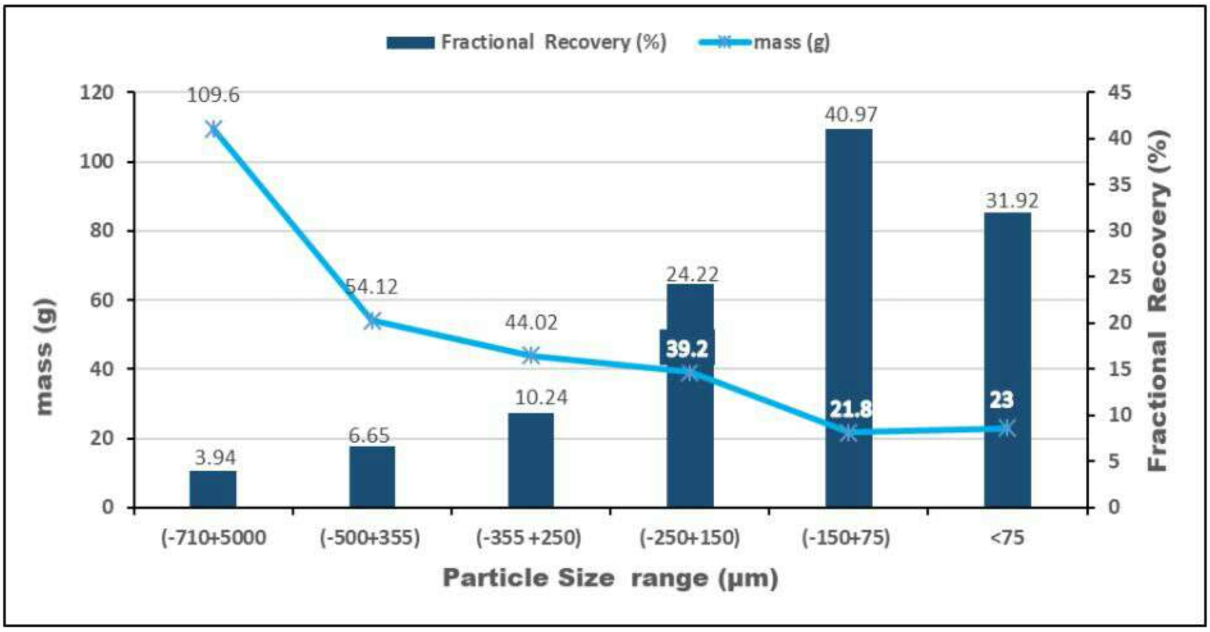

Figure 11 Fractional GRG recovery and mass into the concentrate one.

Figure 12 showed the distribution of gold during the second stage GRG test. In the coarse fraction, the largest gold distribution was found between the class sizes (-355 + 250 µm), but for the fine fraction, it was found between the class size (-150 + 75µm).

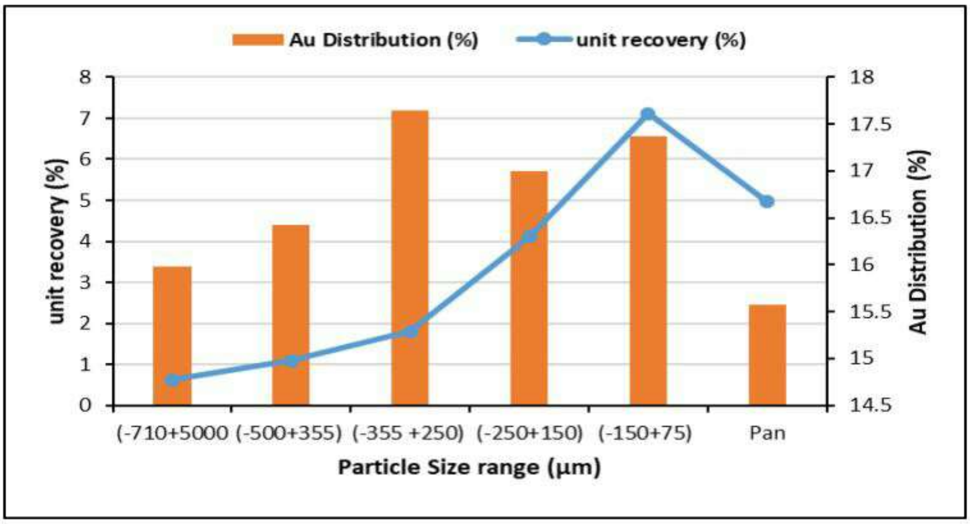

Figure 12. Comparison of Gold distribution and GRG distribution in the second stage shaking table test.

Table 6. Calculated fractional GRG recovery, and gold (Au) distribution of the third stage GRG test using shaking table.

Particle Size(μm)	CONCENTRATE				TAILING			FEED			
	mass (g)	Au(g/t)	Fractional Rec.(%)	Unit Rec.(%)	Mass (g)	Au(g/t)	Fractional Rec.(%)	mass(g)	Au (g/t)	Unit	Dist'n (%)
(-500+355)	77.8	9.13	8.84	1.68	2432.28	3.01	91.16	2410.08	3.33	8030	19.06
(-355 +250)	71	13.94	11.37	2.35	2149.26	3.59	88.63	2220.26	3.92	8710	20.67
(-250+150)	53.5	34.02	21.67	4.32	2702.57	2.4	78.33	2656.07	3.16	8400	19.94
(-150+75)	52	88.27	53.25	10.89	2720.39	1.48	46.75	2672.39	3.22	8620	20.46
Pan	53.2	64.85	41.22	8.19	3079.99	1.6	58.78	3102.19	2.7	8370	19.87
Total	307.5	37.59	27.44	27.43	13084.5	2.34	72.56	13061	3.23	42130	100

The third GRG test was run using the second stage's tailing, which was pulverised to a P100 - 500 μm. In this stage the optimum fractional GRG recovery about 53.25% was observed in the same size class -150+75 μm again (Figure 13).

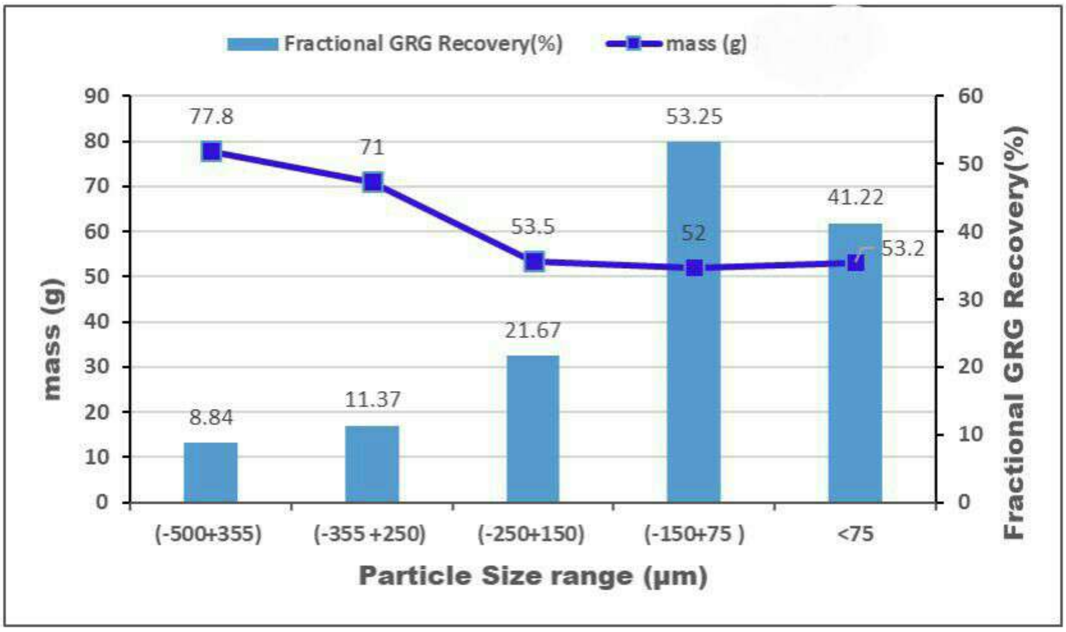

Figure 13. Fractional gold recovery and mass into concentrate three.

The gold distribution shown in Figure 14 illustrates that the largest gold distribution is observed at mean particle sizes 312 µm, and 112 µm in the similar size classes of second stage test.

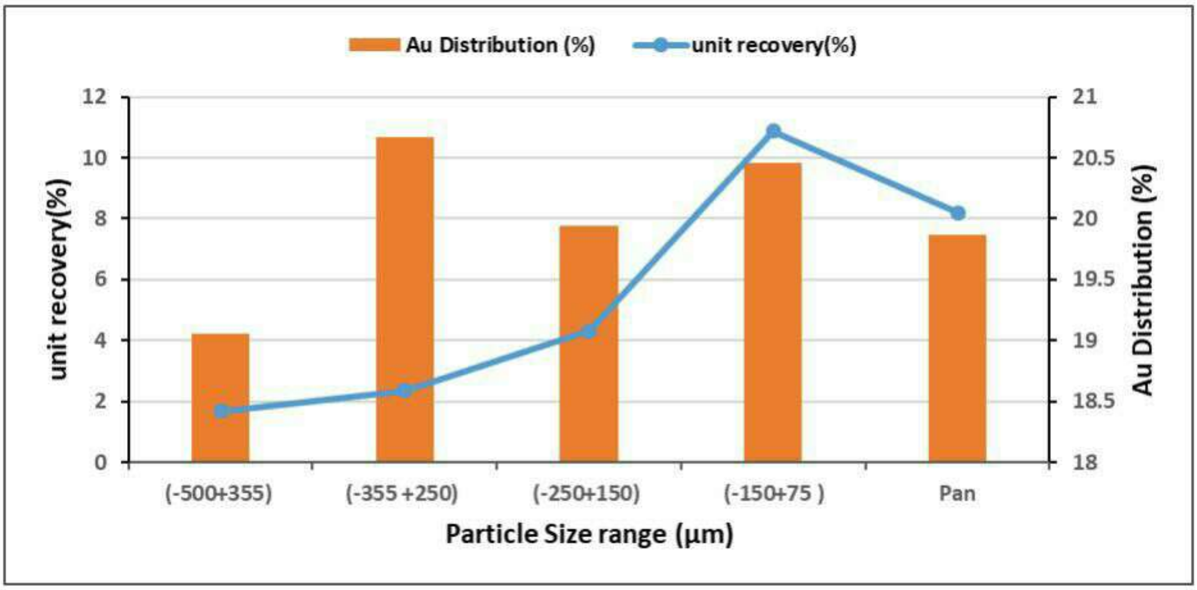

Figure 14. Comparison of Gold distribution, and GRG distribution in the third stage GRG test.

The results of the shaking table test showed that the gold particle size (-150+75 μm) fraction for all three phases obtained the highest percentage recovery values. This might be because the size (-150+75 μm) proportion of the liberated gold particles were an appropriate size for shaking table separation. As see in figures 9,11, and 13 the fractional gold recovery was slightly decrease at the fines class size (< 75 μm). This decrease in recovery at the fine fraction (< 75 μm) probably due to liberated gold particles either becoming too fine, or forming flat, flaky gold particles unsuitable for shaking table separation.

Following the completion of all phases, cumulative recoveries and cumulative distribution of gold were determined to assess the efficacy of the gravity technique employing the shaking table concentrator as a pre-treatment for the Lega dembi and Sakkorro gold mine (see Table 8 and Figure 15).

Table 7. Cumulative GRG recovery and Cumulative Au distribution over 3 Stages.

Mean Size(μm)	Cumulative GRG Recovery (%)				Cumulative Au Destribution (%)			
	Stage.1	Stage.2	Stage.3	Overall 3-stages	Stage.1	Stage.2	Stage.3	Overall 3-stages
1700	0.26	0	0	0.26	4.59	0	0	4.59
1200	0.71	0	0	0.71	8.75	0	0	8.75
855	1.42	0	0	1.42	12.7	0	0	12.7
605	2.45	0.63	0	3.08	16.47	5.33	0	21.8
427.5	3.79	1.72	1.68	7.2	19.95	10.81	6.35	37.11
302.5	5.4	3.53	4.03	12.96	23.26	16.69	13.24	53.2
200	8.23	7.65	8.35	24.23	26.77	22.36	19.89	69.02
112.5	13.37	14.76	19.25	47.38	30.25	28.15	26.71	85.11
<75	17.11	19.73	27.44	64.29	33.33	33.34	33.33	100

Figure.15 displays the total gold recovery acquired via the three phases as well as the contributions made by each stage's recovery to the GRG recovery as a whole. In the first recovery stage only 17.11% of the gold present in the ore was recovered into the concentrate utilising shaking table. The overall recovery for the second and third stage testing was 19.73% and 27.44%, respectively.

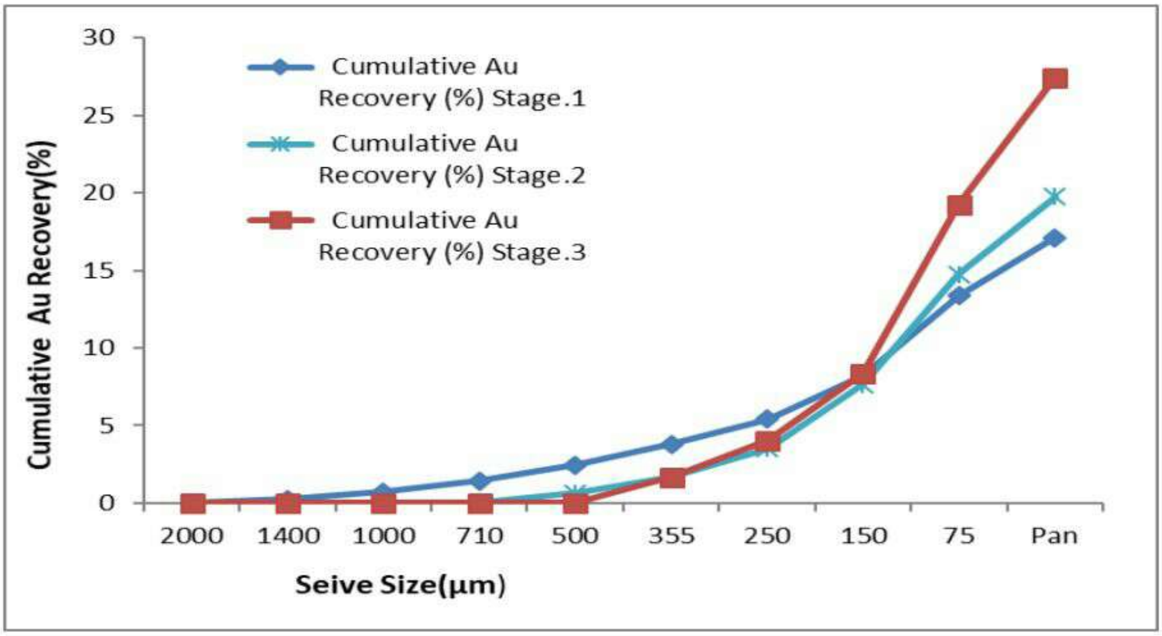

Figure 15.Comparison of shaking table concentrates cumulative GRG recovery over 3 Stages.

The GRG distribution and gold size distribution for samples of gold ore taken from the Lega Dembi and Sakorro gold mines, was displayed on figure 16. The gold distribution, illustrates that an approximately 85%, 69%, and 53% of the available gold in the ore was contained at the average sizes of > 115 µm, ≥200 µm, and ≥250 µm respectively. This suggests that a pre-concentrate coarse gold particle size greater than 200 µm prior to cyanidation treatment helped to reduce leaching kinetics, reduce the amount of gold that was circulating in the milling circuit, and produce high grade concentrate that could then be treated by an intensive cyanidation method.

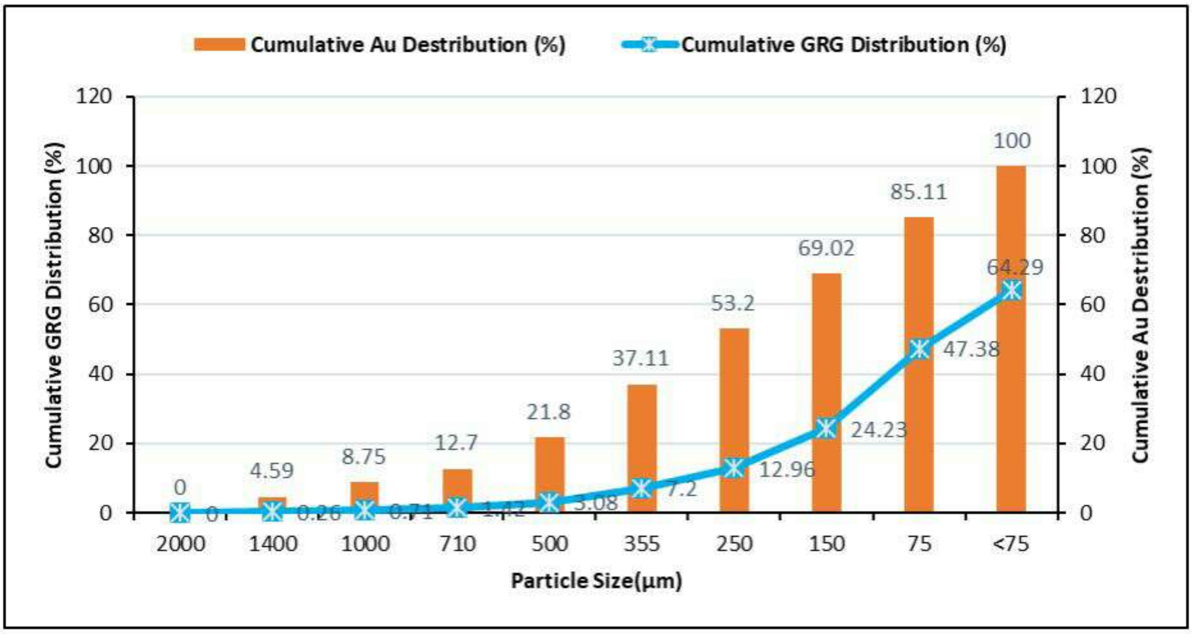

Figure 16. Comparison of shaking table concentrates cumulative GRG distribution, and Cumulative Au distribution over 3 Stages.

As shown in figure 16, the concentrate from the shaking table concentrator had a total GRG recovery of about 64.29%. This showed that the shaking table beneficiation method offered good gold recovery for both coarse and fine particle sizes. However, according to previous studies (Waanders and Quentin Peter 2014), the higher priority is placed on the coarse particle during pre-concentration than the fine particle. But the current findings suggest that the shaking table concentrator produced concentrate with only a 24.23% GRG recovery at coarse particle sizes greater than 200 µm. This demonstrated that the Lega Dembi and Sakarro gold ore's pre-concentration using a shaking table was not effective.

5. Conclusion and Recommendations.

As a consequence of this investigation, the gravity recoverable gold (GRG) content of the Lega Dembi and Sakarro gold ores was successfully determined using the shaking concentrator. According to the GRG test results, the GRG recovered into the first, second, and third shaking table concentrates were 17.11%, 19.73%, and 27.44%, respectively. GRG recovery over three stages indicated that the concentrate from the shaking table concentrator had a total GRG recovery of about 64.29%.

In addition the optimum size range for gravity concentration of gold ore sample taken from Lega Dembi and Sakaro gold mine was studded. The shaking table test findings demonstrated that for all three stages, the gold particle size (-150+75 µm) fraction produced the highest fractional recovery values. This may revealed that the liberated gold particles at size more amenable to shaking table separation was found at gold particle size (-150+75 µm) fraction.

In this study size analysis and assey by fraction was also conducted to determine the GRG, and Au size distribution within the ore sample. The size distribution of gold shows that, 85%, 69%, and 53% of the gold that was present in the ore was found at average sizes of ≥ 115 µm, ≥ 200 µm, and ≥ 250 µm respectively. As previous study on milling circuit (Laplante and Gray, 2005) demonstrated that an average, gold particles larger than 75 µm will circulate 50-100 times in a grinding circuit before reporting to the down stream processing. In this study the size distribution of gold shows that approximately about 85 % of gold within the ores was present at gold sizes ≥ 75 µm. This gives the company verifiable proof that the ore's significant amount of coarse gold may causes the gold to circulate during grinding and hydro-cyclones classification.

In addition recent study on gold cyanidation leaching (Yahaya.I et el., 2022) demonstrated that to leach gold particles coarser than 75 µm > 24 hours duration of leaching times were necessary. The current findings indicated that the shaking table concentrator produced concentrate with only a 47.38 % GRG recovery at coarse particle sizes greater than 75µm. This proved that the pre-concentration process employing a shaking table for the Lega Dembi and Sakaro gold ore was not effective. However recycling of the middling fraction and unstable nature of the operation, is challenging to assess the shaking table's performance correctly.

- Therefore I will recommended that the company to conduct further study into more suitable pretreatment techniques such as inline jigging or centrifugal gravity knelson concentrator.

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