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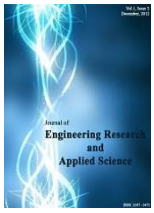

Development of a Thermodynamically Froth Flotation System for Gold Recovery from Ores

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Abstract
Gold production is very critical to national development. It supports socio- economic development of a nation; therefore there is a need for constant research in the area of enhancing its concentration in such a way to avoid environmental degradation and risk. A laboratory flotation machine for the recovery of gold from their ores was developed using thermodynamically froth design principles. The units and systems that constitute the machine are: cell unit of 5 litres water capacity, where pulp is contained and bubbles are generated; cell chassis, which consists of the frame base, frame stand and frame table which serves as support for different components-the motor, cell unit, and the shaft of froth flotation machine; agitation system (impeller), consists of impeller shaft screwed to the impeller disc for the purpose of agitating the pulp and reagents for proper conditioning; and control unit which consists of the speed controller, air regulator and air flow meter. Fabrication of the machine was carried using locally sourced materials by soldering and welding techniques. The machine was tested and the result was compared with similar imported standard machine. The results revealed gold recoverability difference of 3.45 % between the standard and the fabricated machine. The locally fabricated gold refinery, apart from its 70% cost savings, will enrich gold mining industries and promote foreign exchange earnings as well.

Keywords: *Gold-refinery, Thermodynamically-froth, Flotation, Gold-enhancement*

1. Introduction
Nigeria as a nation is endowed with a lot of metallic minerals, industrial mineral and rare or precious stone among which is Gold [1]. Minerals are essential component of nation's material and economic base. The wealth of any nation is not governed by the abundance of these mineral deposits, but, by the method of exploration, exploitation, processing, extraction and utilization of the end products.

Mineral resources refer to the totality of known and unknown mineral deposits in a district or region [2]. Minerals are homogenous, naturally occurring solid substances which have definite chemical composition and atomic structure. Mineral processing is an intermediate processing between mining of ore and extraction of valuable metals.

Gold as one of the most precious metals has a remarkable position in the world economy. Gold has its application in the production of jewelries, coinage, etc. It is alloyed with silver for making wear resistant products. Gold is also used in the manufacture of spinets, synthetic fibres, thermocouples and in electronic industries. Gold-Nickel and Gold-Iron alloys are magnetic in nature and are used in computer memory devices [3]. Gold occurs primarily as fine grains or dusts (a few microns to 100 microns in size) in small quartz veins, quartz stringers, tourmaline – quartz veins and aphlitic dykes which are either conformable with or cross – cutting diverse rocks types including amphibolites, schists, phyllites, quartzites, gneises, pegmatites and granites. However, gold nuggets, which have been found occasionally in the gold field, are probably products of near surface neomineralization, resulting in the formation of large gold grains. In general, the three gold fields (Zamfara-Kebbi, Birnin, Gwarri-Minna and Ife-Ilesha) are located in the schist belts predominantly exposed in the western half of Nigeria. The Nigerian Mining Corporation (NMC) announced the discovery of new gold deposits in Niger, Osun, and Sokoto States [4].

Gold production is very critical to national development. It support socio- economic development of any nation, therefore there is a need for constant research in the area of its comminution and concentration in such a way that will not engender

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environmental degradation and pose no risk on life. The use of cyanide for concentration during field processing is a common practice but neither cyanide nor mercury is environmental friendly. Recovery of gold in this way may lead to increase in the concentration of mercury and cyanide in nearby rivers [3]. In this regard, froth flotation is gainfully employed for the processing of gold ores [5]. Therefore, this work focuses on the development of laboratory froth flotation machine for the recovery of gold from their ores, in which the specific objectives are to: design a froth flotation machine for gold recovery; fabricate the apparatus designed in (a); and evaluate the gold recoverability performance of the apparatus.

Several methods have been utilized for the dressing of gold ore. These methods have either suffered low recovery or low economic friendliness. Gold is an inert element but has affinity for certain elements, such as oxygen and mercury. Chemical leaching is mostly used in large scale mining operations for metal recovery, but has been increasingly adopted in small scale mining because of its high gold recovery rate and low cost. Cyanide is often the preferred chemical used in leaching but highly poisonous, this pose great risk on life. Also, amalgamation of gold using mercury produces amalgam of gold as the leached precipitate. This method has been reported to be toxic.

Environmental protection has become the focus of world - wide research in the gold mining industry. The preferred processing technique for a particular ore is likely to be the one with the lowest capital and operating cost, commensurate with both speed of processing and highly percentage recovery. Froth flotation technique is the best and most used to separate solids of similar densities and size, which prevent other types of separation based upon gravity that might otherwise been employed. Despite its usefulness, this machine is very expensive and not easy to get in the country. This is the thrust for designing the machine locally as an alternative for the imported ones. The solution that is provided in this study is on a laboratory scale and will be useful in the area of teaching, research and technology development. This study covers: design and fabrication of a froth flotation cell; and performance test of the machine using a gold ore obtained in a location in Nigeria.

The concentration of gold in quartz vein varies from 10.0 to 6280.0 ppb. [6]. At these concentrations 20 or 30 tons of rock must be processed to extract a single ounce of precious gold. The world’s top five gold producing countries are China, USA, Australia, Russia and South Africa. Others are Peru, Indonesia, Ghana, Canada and Uzbekistan [7, 8].

Gold deposits are widely spread in Nigeria [9]. Production decline during the Second World War, Mines were abandoned by colonial companies and production never recovered until 1980s. Although gold ore deposits are known to exist, most of the outputs are from alluvial, elluvia placers and primary veins from several parts of supracrustal (schist) belts in northwest and southwest of Nigeria [4]. The most important occurrences are found in the Maru, Anka, Malele, Tsohon Birnin Gwari- Kwaga, Gurmana, Bin Yauri, Okolom-Dogondaji and Iperindo areas, all associated with the schist of northwest and southwest Nigeria [10]. Primary gold mineralization in the schist belt commonly occurs in quartz vein within several lithologies [6].

Gold is a soft yellow metal, with highest ductility and malleability of any metal [11]. This unique set of qualities has made it a coveted object for most of human history in every civilization [12]. The only natural isotope of gold is ^{197}Au; however, 19 isotopes ranging from ^{185}Au to ^{203}Au have been produced artificially [11].

Gold can be alloyed with other metals to improve its strength, hardness etc. [13]. Gold alloys are used for fillings, crowns, bridges, and orthodontic appliances [13]. Gold is used in electronic mainly in the form of electroplating chemicals, gold bonding wire and sputter targets [14]. Gold is also used on connectors and contacts because it has excellent corrosion resistance, high electrical conductivity and, alloyed with small amounts of nickel and cobalt, has good wear resistance [14]. It also finds its application in carat jewelries, legal tender (gold coin) and many other applications in alloyed forms [15]. Other uses of gold are for making of gold flakes for radiation control coating for aircraft, dental restoration material in biomedical application, etc. [16].

Mineral processing is a process of physically separation of the grains of valuable minerals from the gangue minerals to get the enriched portion known as the concentrates. Mineral processing involves two major operations namely comminution and concentration. Comminution is the gradual reduction of a large coarse hard mineral to a finer size by crushing, grinding or attrition for direct use or further processing, while concentration is the separation of valuable minerals from their associated gangue. Mineral processing reduces the volume of materials to be handled by the extractive metallurgy, thereby reducing the amount of energy and reagents that is required to produce the pure metals; it also reduces the bulk and the weight of the handling materials. The various concentrating methods are: Sorting; Gravity concentration; Magnetic separation; High tension and electrostatic separation; Heavy medium separation; Flotation; and Amalgamation.

Comminution in mineral processing plants takes place as a sequence of crushing and grinding. Size analysis is used to determine the quality of grinding and establish the degree of liberation of values from the gangue at various particle sizes. Enrichment is achieved by washing and separation. While washing can be done by using log washers, wet screen, aquamator separator and tumbling scrubbers, the popular separating techniques in mineral processing are gravity separation, magnetic separation and flotation. The criteria on which these methods are assessed are presented in the past studies [17-19].

Flotation process is controlled by the following three principal entities: flotation thermodynamics; flotation kinetics; and flotation hydrodynamics. A typical laboratory flotation cell essentially consists of a vessel or a tank fitted with an impeller or rotor. The impeller agitates the slurry to keep particles in suspension, disperse air into the bubbles and provide an environment in the cell tank for interaction of bubbles and hydrophobic particles and their subsequent attachment and therefore separation of valuable mineral particles from the undesired gangue mineral particles. Flotation works efficiently only if:

i. The particles to be floated are fully liberated from the gangue. The liberated particle (i.e., the flotation feed) from which the selected particles are to be floated is conditioned with appropriate reagents. This suspension of about 1: 3 solids to water by weight constitute floatation pulp.
ii. The pulp is placed and agitated using impeller in a suitable container called a flotation cell or tank (Fig 1).
iii. Air is drawn in or sometimes fed into the cell near the impeller to form fine bubbles. These bubbles collide with the particles, attach to those particles which have the acquired hydrophobicity, and rise to the surface where they form a froth, which is removed as flotation concentrate (a froth product) by skimming. The hydrophilic particles that are not floated with the bubbles remain in the pulp, and are removed from the cell as tailings (Figure 1).

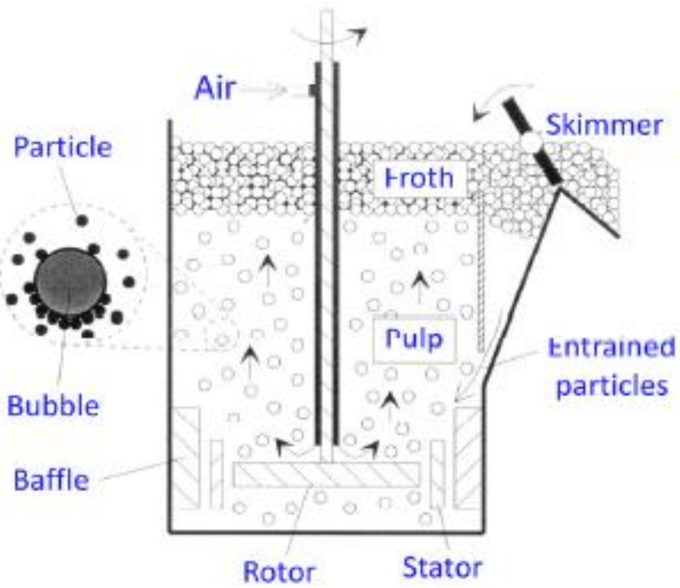

Figure 1: Schematic representation of flotation process.

The manner in which bubbles and particles interact with each other depends on the cell operating conditions and the type of flotation machine used. Flotation machines, in general, may be categorized into four different classes: (i) mechanical or conventional cells; (ii) energy-intensive pneumatic cells; (iii) column cells; and (iv) froth separators, of these, mechanical flotation cells have dominated the mineral industry since the early days of flotation and account for a significant amount of minerals processed [20].

A mechanical flotation cell essentially consists of a vessel or a tank fitted with an impeller or rotor. The impeller agitates the slurry to keep particles in suspension, disperses air into fine bubbles and provides an environment in the cell tank for interaction of bubbles and hydrophobic particles and their subsequent attachment and therefore separation of valuable mineral particles from the undesired gangue mineral particles. The bubble particle aggregates move up in the cell by buoyancy and are removed from the cell lip into an inclined drainage box called a launder. The launder product is commonly known as concentrate. The particles that do not attach to the bubbles are discharged out from the bottom of the cell tank to the discharge or tailings box.

In pneumatic cell, suspension of solid particles in water is achieved by the compressed air being suitably dispersed throughout the volume of the cell. It employs a perforated grid or pipes arranged in an appropriate position near the top of the cell. This allows a thick bed of froth to be formed [20]. In this type of cell, pulp and air are ejected into the cell through a nozzle to produce intimate contact between air and particle. This usually means that an excessive amount of air must be used, and as a result these types of machine are not common as mechanical cells.

Other methods of gold recovery have been developed by researchers. In the recent past, gold has been recovered from: secondary waste of PCBs using electro-Cl_2 leaching in brine solution and solvo-chemical separation with tri-bytyl phosphate [21]; porous covalent organic frameworkbased hydrogen-bond nanotrap [22]; advanced hydrometallurgical approaches [23]; reduction roasting, mechanical activation, non-cynide leaching, and magnetic separation [24]; falcon concentrator [25]; micellar-enhanced ultrafiltration process [26]; e-waste using free standing nanopapers of cellulose and ionic covalent organic framework [27]; dual thiols-decorated metal-organic framework [28]; modulating skeletons of covalent organic framework [29]; e-waste by imidazolium-based poly (ionic liquids) [30]; post-synthetically functionalized covalent organic framework [31]; enrichment of the technogenic wastes [32]; and SERS detection and surface acoustic waves [33]. Many of these studies failed to consider mechanical aspect of the recovery system and at same time devoid of recoverability evaluation which requires comparison of recoverable gold and cost using standard mechanical equipment. These gaps are filled by this study.

2. Methodology

2.1. Design consideration

In order to enhance high efficiency performance of the designed components when in operation, adequate knowledge of engineering materials and their properties are taken into consideration. These include mechanical, physical, chemical and dimensional properties as well as the material availability. The following factors are considered:

i. Product specification relating factors. These include complexity, maintenance, human factor, and ease of operation, frequency of feature, initial cost and operating cost.
ii. Design specification relating factors. These include complexity, form and structure, operating load, flexibility, lubrication, thermal and electrical considerations as well as the expected life.
iii. Materials related factors. These include strength, ductility, toughness, stiffness, corrosion and wear resistance.
iv. Manufacturing related factors. These include available fabrication process, accuracy surface finish, shape, size, quantity, delivery time, cost and required quality.

2.2. Target Specification

The specification targets are:

i. Laboratory equipment: the target is to use the machine in a laboratory.
ii. Cell capacity: The capacity of the cell is limited to 3 litres. The maximum capacity of water for this Cell is 5 litres (5000 cm^3) of water.
iii. Corrosion resistant material: In froth flotation machine set up, the agitation system and aeration system are lowered into water inside the cell so as to generate, break and sustain bubbles in the cell. Due to water contact, it is required to use a corrosion resistant material for the components of the two systems.
iv. Bubble (froth) collection: In froth flotation technique the froth which is particle-bubble attachment is the target product. This froth is collected using paddle.
v. Transparent cell: Sighting of activity in the capture of different bubble sizes generated inside the cell is needed for image analysis. Due to this specification, it is technical to use a transparent material to enhance clarity of snapshot from any side of the cell.

vi. Machine source of energy: The target source of energy of this machine is electricity. A suitably 220-240V electric motor is to be used to rotate the impeller system.

vii. Durability: durability is always a leading factor in design. This work is targeted to design components as a supportive structure to different and whole units of the machine and to the machine as whole.

2.3. Description of Components

The units and systems that constitute the machine are;

Cell Unit: The cell unit is tank where pulp is contained and bubbles are generated. The cell was designed to hold 5 litres of water which is the maximum volume of water that can be supplied into the cell.

The dimension of the cell can be calculated by assuming an initial cube for the cell.

Volume of a cube = L^3

To get the length (L) of the cube, the target volume of the cell is equated to the volume of the cube

L^3 = 5 Litres

Converting litres to millimeters cube (mm3), 1 liter = $10000000mm^3$

$L^3 = 5000000mm^3$

Taking the cubed root of both sides

$L = \sqrt[3]{5000000mm^3} = 170.99mm$

The length of the tank was approximated to 171mm for tolerance and easy design. With reference to this length, the geometry of the cell can be gotten out to dimension.

Stainless steel was used for this purpose for durability and to avoid corrosion. It is also easy to work with, in cutting, filing and joining together to form a cell. Stainless steel is a steel alloy, with highest percentage contents of Iron, chromium, and Nickel, with a minimum percentage of 10.5% chromium contents by mass and a maximum of 1.2% carbon by mass.

The Cell Chassis: The chassis consist of the frame base, frame stand and frame table which serve as support or house for different components (the motor, cell unit, and the shaft) of froth flotation machine.

Mild steel angle bar and mild steel sheet is preferable to be used in fabricating this unit. This is because mild steel has good machinability and weldability property. It is the general workshop construction steel and is economical compared to other types of steel materials. The chassis was painted for aesthetics and corrosion protection in order to facilitate longevity of mild steel material since the operation of the machine is a wet operation.

Agitation system (impeller): This consists of impeller shaft screwed to the impeller disc. It is used for the purpose of agitating the pulp and reagents for proper conditioning and to achieve hydrodynamics needed condition. Diffuser is connected to an electric motor shaft mounted on top of the electric motor seat. The diffuser facilitates the spreading or distribution of bubbles over a wide range in cell. Stators of 2.5 mm thickness were attached to the diffuser to enhance its effectiveness. Material selection for this unit is stainless steel to guard against corrosion. Stainless steel, was used for impellers because of its availability; superior performance in low temperature; good degree of weldability and formability; and high resistance to corrosion.

Aeration System consists of the aeration pipe, air cylinder, and hose through which air that is needed for the aeration of the pulp enters the cell (tank). Air cylinder uses the stored potential energy of a fluid; this is converted to kinetic energy as the air expands in an attempt to reach atmospheric pressure. The aeration pipe introduces air into the cell (tank). A 10 mm diameter pipe is used due to its availability in the market and this also is good for the cell specification. As regards material selection, a corrosion resistant material is used because the lower part of the pipe would have to be inside water. Copper tube is chosen for this unit because of its: corrosion resistant; good ductility; and readily available. The range of aeration system used in this study is between 1 to 5litres per min. (reasons).

A hose is a hollow flexible tube designed to carry fluids from one location to another. The hose carries compressed air from the air cylinder to the aeration pipe then to the cell (tank). The hose and the aeration pipe were properly fitted to avoid leakage of the air. The diameter of the hose used for this study was 10mm because of the size of the aeration pipe. Metal clip was used to fasten the hose to the aeration pipe on one side and another metal clip was used to fasten the hose to the air regulator at the other end to ensure air tight system.

The drive system comprises of electric motor, electric motor seat and the connector. The electric motor with three step speed control of 1000rpm, 1200rpm, and 1400rpm was used due to: low cost, availability, handy, easy mounting (no need of pulley system), easy starting load. Electric motor seat design served as: support/base for the electric motor which allows enables easy mounting, and a protective covering. The electric motor was screwed to it. The connector was designed to connect the impeller shaft to the electric motor shaft by means of screw.

The control unit consists of the speed controller, air regulator and air flow meter. Speed controller is capable of varying the speed of a motor between 1,000rpm and 1,300rpm.The air regulator controls the volume of air going out of the cylinder. This is directly fixed on top of the cylinder. The air regulator was purchased after checking: the minimum and maximum flow rate of the metre; the minimum and maximum process pressure; and the minimum and maximum process temperature. The materials used for the fabrication of this machine were purchased at Akure and Lagos cities, Nigeria (Table 1).

2.4. Components Manufacturing

Component manufacturing involves the various processes taken to arrive at the final desired components. It involves the process of fabrication and machining to arrive at the desired shape and dimension.

Fabrication is the manufacturing processing which an item is made from raw or semi-finished materials through cutting, bending and joining. Dimensions of each component were accurately measured using Rotary set. The Cell was cut and welded together. It was later tested to avoid water leakages. The materials used for the impeller was cut using chisel and hacksaw. And the aeration system were cut, bent and welded to form the desired shape, this was later ground and threading was done on it. The Aeration pipe was also cut, bent and brazed. Oxyacetylene welding machine was used in brazing the joints together.

2.5. Assembling of Components

The steps taken in assembling of the components are:
Step 1: The frame which is made up of the frame base, stand and frame table were fastened together with bolts and nuts. The electric motor seat was placed and fastened on the frame stand.
Step 2: Thereafter, The frame table is placed and fastened on the frame base using bolts and nuts.
Step 3: The cell chamber is mounted on the frame table.
Step 4: The impeller is made up of the diffuser or distributor and the agitator (the shaft). The impeller shaft is coupled with the diffuser and then was placed gently inside the cell
Step 5: After this the electric motor was mounted on the electric motor seat on the frame stand. Then the electric motor shaft was fastened to the impeller shaft with the aid of a mild steel connector.
Step 6: Finally, the aeration pipe was inserted vertically into the cell chamber. The rubber hose serves as connector which links the copper aeration pipes to the air cylinder, while the air flow metre was fixed in between them (Figure 2). The bill of engineering material estimation is shown in Table 1.

Table 1. Bill of Engineering Material Estimation

Material	**Quantity**	**Cost(₦)**
Stainless steel sheet	1 no of 4ft by 4ft x 2mm	50,000
Stainless Steel rod	1	5,000
Copper tube	4ft length	10,000
Mild steel sheet	1no of 4ft x 4ft x 2mm	25,000
Mild steel plate	1 no of 4 ft x 4ft x 2mm	25,000
Mild steel Angle bar	1 no of 16 ft length	17,500
Electric Motor	Bought out 1	**30,000**
Air Cylinder with nitrogen gas	Bought out 1	25,000
Air Regulator	Bought out 1	7,500
Hose	Bought out 1	5,000
Cost of fabrication		**200,000**
Other costs		**40,000**
Total		**240,000**

Tools and equipment cost, production process cost, transportation and material handling cost, among others are excluded from the total machine fabrication cost. This was estimated as 20% of the fabrication cost, and summed up to making a total of N240,000 ($240).

2.5. Performance Evaluation/Experimental Setup

The setup of this machine was carried out by coupling the purchased component to the assembled designed components. After this, the machine was checked round to ensure all the parts are correctly and well fitted. The machine was placed on a flat surface for better positioning of the machine (Figure 2). The aeration system was achieved by fixing the air regulator with the gas cylinder. The machine was set up for performance tests. The weight and the percentage composition of gold concentrate recovered using the machine (Figure 2) was compared with that from a standard gold recovery flotation cell (Figure 3).

Figure 2. Recovery of gold using Fabricated flotation machine after Aeration

Figure 3. Recovery of gold ore by a standard flotation Cell

The gold ore was first comminuted, after which particle analysis was carried out to establish the degree of liberation, finally the comminuted sample was taken for compositional analysis in order to know the elemental composition of the raw sample in accordance with American Standard for Testing Method. 100 g of gold ore of 150 µm size was weighted and put into a 250 mls flotation tank and mixed with 1000 mls of water and then agitated to form pulp of 100 g/lt., conditioning of the pulp was done at impeller speed of 1200 rpm. The initial pH of the pulp was checked by using hand held pH meter, and it was found to be 5.6, this was raised to pH of 9 by adding 0.5 g of soda ash. The gold was activated by adding 0.5g of $CuSO_4$. 0.5g of Potassium Amyl Xantate was introduced into the pulp as collector. 0.5g of Methyl Iso Butyl Carbinol was used as the frother. The pulp was then aerated and the froth was collected after dried, weighted, and recorded. Each reagent was added to the pulp after two minutes.

On the developed machine (Figure 2) one-hundred gram (100g) of the comminuted sample was placed inside the cell chamber. 1000mls of water was added gently to avoid turbulence and splashing of water because of the components inside the cell. The head of the impeller (diffuser) was lowered into the cell chamber but not allowed to touch the bottom of the cell chamber so that unwanted minerals will not float or come up with the froth. The tip of the aeration pipe was also lowered gently into the chamber and was suspended by plastic clip. The electric motor was connected with an electrical source, and the sample was subjected to the same condition as the one floated using a standard flotation cell (Figure 3) [34]. This was done on five replicates, and average weight values, using electronic weighing device, of recovered gold (Figure 4) from the froth of concentrated gold were recorded.

3. Results and Discussion

The results obtained from the experiment using developed machine are presented in Tables 3 and 4, respectively.

It is clear from the results (Tables 3 and 4) that standard Denver machine can recover and concentrate more gold (17.83g, 29.72%) than the fabricated machine (15.76g, 26.27%). This shows that Denver machine is better than fabricated machine in term of gold recovery by 3.45%. It is further revealed (Table 4) that gold recoverability difference of 2.07g (3.45%) between standard Denver and fabricated machine is not high enough to call for rejection of the developed technology because the difference cost implication would eventually be consumed by the economic benefit of utilizing indigenous technology in terms of empowerment enhancement and foreign exchange conservation.

It is shown from Table 5 that a cost savings of about 70% is expected when the locally fabricated refinery is applied instead of standard Denver machine. On this basis, adoption of this refinery is expected to enrich national gold mining industries and conserve foreign exchange at the same time.

Figure 4. Weighing of sample and recovered gold concentrate

Table 3. Weight Recovery using Denver Flotation Machine (DFM)

S/N	Weight of Raw Sample (WS)	Weight Recovered (WR)	Recoverability WR/WS (%)
1	20g	5.50g	27.5
2	40g	11.01g	27.5
3	60g	16.51g	27.5
4	80g	22.01	27.5
5	100g	34.11g	34.11
Average DFM	60g	17.83g	29.72

$\%W_r = (W_{tr}/ W_{ts})\ 100 = (17.83/60) \times 100\% = 29.72\%$

Table 4. Weight Recovery using Fabricated Flotation Machine (FFM)

S/N	Weight of Raw Sample (WS)	Weight Recovered (WR)	Recoverability WR/WS (%)
1	20g	4.01g	20.01
2	40g	8.02g	20.01
3	60g	12.02g	20.03
4	80g	22.31g	27.89
5	100g	32.45g	32. 45
Average FFM	60g	15.76g	26.27
Average DFM from Table 3)	60g	17.83g	29.72
Differences (D)	-	(2.07g)	(3.45%)

$\%W_r = (W_{tr} / W_{ts})100 = (15.76/60) \times 100\% = 26.27\%$

Table 5. Cost comparison of the floatation machines

S/N	Fabricated floatation machine price (2024) (F) ₦/$	Denver laboratory floatation machine price (Denver d12, 2024) (D) ₦/$	Cost savings (D-F)/D. ₦/$(%)
1	240,000	800,000	560,000 (70%)
2	240	800	560 (70%)

4. Conclusion

Development of Flotation Machine for Solid Mineral separation has been achieved. The performance of the machine was evaluated by using it for froth flotation of gold ore. The weight of the gold recovered was compared to the weight of gold recovered from that of Denver laboratory flotation machine. The following conclusions can be drawn from this study:

i. It possible to develop a gold recovery machine using locally sourced material with acceptable performance as compared with similar ones that are available in the international market places.
ii. Fabricated and standard machines are capable of recovering 15.76g and 17.83g of gold from the experimented 60g of gold ore samples which show a good and close comparative result between the two mechanical methods.
iii. The low weight difference of gold concentrate between the two methods is sufficient to accept the replacement of the imported gold recovery machine with the one locally made.
iv. Besides, the low cost of machine developed (N240, 000, ≈$240) as compared to the Denver machine (N800, 000 ≈$800) is another added advantage of its adoption to concentrate gold.
v. Limitation of this study is non-evaluation of mechanical, physical, chemical, atomic, thermal, electrical, and among other properties of the gold products, as compared to the established standard properties of gold.
vi. Also, the developed machine should be used further to concentrate other ore samples in order to generalize its application.

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