# Effect of Riffle Height and Spacing of a Sluice Board on Placer Gold Recovery*

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## Abstract

Sluicing is the preferred mineral processing technique for the treatment of placer gold-bearing alluvium for small scale and artisanal miners in Ghana because sluice board is perceived to be the most cost effective device. However, there are differences in approaches from design to operation. In this work, about 50 kg of ore was obtained from "Peace School" small scale mining site near the University of Mines and Technology, Tarkwa. It was processed to determine the effects of riffle height and spacing on gold recovery. It was confirmed that, in order to trap a greater percentage of gold particles, the height of the riffle ought to be higher than the suspension height of the gold. The suspension heights of the gold particles of the various operational regimes of the sluice board at superficial velocities of 0.5 m/s, 1.0 m/s, 1.5 m/s and 2.0 m/ were 0.9 cm, 1.2 cm, 1.5 cm and 2.9 cm respectively. Analysis of concentrates showed that, 85.4% of gold was recovered during sluicing at approximately 1.0 cm riffle height. The lowest recovery was recorded at 0.5 cm riffle height. Gold recovery was also affected by riffles spacing. For the indicated speeds and the riffle heights the necessary spacing should not be more than 20 cm. The peak recovery was obtained at a riffle height of 1.0 cm but dropped after 20.0 cm spacing.

**Keywords:** Sluice Board, Riffle Height, Gold, Rifle Spacing

## 1 Introduction

### 1.1 The Interaction between Mineral Particles and Water on the Board

Flotation has become the method of choice for preconcentratiuon of ores. However, gravity concentration continues to play significant role in the beneficiation of ferrous minerals, nonferrous metals, rare earths, and prevails in the processing of coal, precious minerals, and alluvial ores. All the gravity concentration methods are based on the principles and laws that apply to the type of medium in which the enrichment takes place. The settling and sedimentation of an object in any medium occurs under the influence of the force of gravity which is equal to the weight of the object in that medium of separation. A Gravity concentration device like sluice board is very popular among small scale and artisanal miners in Ghana. However, knowledge about effective design parameters is inadequate. The objective of this work is to contribute to filling this gap by proposing design of optimum operational parameters by determining the effects of the modified riffles height and spacing of the sluice board on free milling or alluvial gold recovery. The jet of water which flows on an inclined surface is used to separate particles using density on sluice boards and the effective particle separation depends on the kinematics structure of the flow. According to Zhukovski (1949), the nature of fluid structure containing solid particles is influenced by the whirl flow turbulence at the bottom of the particle and not the whirl flow turbulence formed in the flow because the angular speeds of the whirl flow inside the water jet and its components are lower than the elliptic whirl flow at the bottom of flow under the particle. Thus, the suspension of mineral particles of the inner part of the flow on an inclined plane occurs and this is maintained by the vertical component of the speed whose values ae determined by the mass of the water displaced by the whirl flow at the bottom of particles. The latter sends water towards the inner parts of the flow in separated portions after which the whirl flows are broken into smaller units, followed by the formation of new whirls. The resistance to flow on an inclined plane mainly depends on the roughness of the surface. Thus, the opposing surface frictional forces from the surface of the board cause the emergence of whirl flows (Fomenko, 1980). Therefore , as the flow encounters the frictional forces from the bottom, rotational movements are created which cause the whirl flows which are then enforced by the horizontal axis of the alternative descending and ascending currents. It is important to note that the solid particles of the fluid also play various complimentary roles in the occurrence of whirl flow and turbulence. Velikanov (1946), thus, established a qualitative analogy between large scale whirls and rotating spherical bodies on an inclined surface. In this model, it is evidenced that two rotating spherical particles of reduced sizes which are widely separated do not have mutual interaction of whirls (Fig.1). However, the rotation of bigger particles creates intense interlocking whirls caused by friction and particle movements which are transmitted from one particle to another. For this reason, between two neighbouring whirls, there is a gradual transition
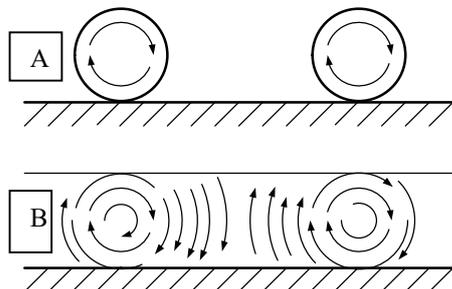
from ascending to descending movement. The whirls flow smoothly in the upper part of the fluid, but it is retarded at the bottom by opposing frictional forces.



**Fig. 1 (a) Movement of Spherical Solid Particles and (b) Turbulent Whirl Flow**

The fluid which moves on an inclined surface whirls to different directions, and creates complicated conditions for the movement of mineral particles. The water flows on an inclined surface under the influence of the force of gravity. With a free limit of flow (Fig. 2), the pressure is constant along this limit and does not depend on the distance thus:

$$\frac{\partial p}{\partial x} = 0 . \tag{1}$$
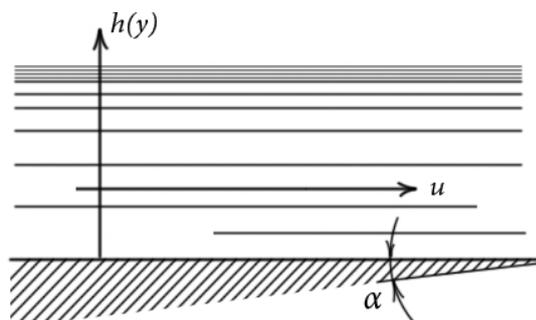


**Fig. 2  Movement of Fluid on an Inclined Plane**
**Source: Fomenko (1980)**

The equation for stationary movement $\frac{\partial p}{\partial x} = 0$ of non-compressible viscous liquid with constant $\rho$ has the following expressions as illustrated in Fig. 2 (Fomenko, 1980):

$$F_x = \frac{1}{\rho}\cdot\frac{\partial p}{\partial x} + \frac{d^2 v}{dy^2} + \frac{d^2 u}{dz^2} = 0 \tag{2}$$

$$F_y - \frac{1}{\rho}\cdot\frac{\partial p}{\partial y} = 0 \tag{3}$$

$$F_z - \frac{1}{\rho}\cdot\frac{\partial p}{\partial z} = 0 \tag{4}$$

Where, $F_x$, $F_y$ and $F_z$ are projections of force of gravity in the x-, y- and z-axes respectively;

$\rho$ is the density of the liquid;

$\upsilon$ is the kinematic coefficient of viscosity of the liquid; and

$u$ is the whirl speed of the flow.

The projection of the force of gravity in the direction of the movement of flow is equal to:

$$Fx(v) = mg\sin\alpha \tag{5}$$

For that reason, the first equation can be written in the form:

$$\frac{d^2 V}{dy^2} = -\frac{mg\sin\alpha}{v} \tag{6}$$

Where the liquid gets in contact with the surface of the sluice board, the height of fluid, h = 0, and v = 0. On the contrary, the force of viscosity in the free limit of flow becomes 0 at the upper zone, H, (Fig. 2) and the maximum speed takes place at the upper limit of the fluid where  h = H:

$$\frac{dV}{dt} = 0 \tag{7}$$

Integrating equation (6), gives equation (8):

$$V = -\frac{mg}{v}\sin\alpha\frac{h^2}{2} + c_1 h + c_2 \tag{8}$$

Taking into consideration the boundary conditions,

$$c_1 \frac{mgH}{v}\sin\alpha;\ c_2 = 0 \tag{9}$$

In this way, the speed $v$ at a distance $h$ to the surface would be equal to:

$$V = -\frac{mg}{v}\sin\alpha\frac{h^2}{2} + \frac{mg}{v}\sin\alpha Hk \tag{10}$$

or better

$$V = -\frac{mg}{v}\sin\alpha(Hh - \frac{h^2}{2}) \tag{11}$$

If $\frac{mg}{2v}\sin\alpha$ is assumed as a constant magnitude $k$, Equation (10), becomes

$$V = k(Hh - \frac{h^2}{2}) \tag{12}$$

The maximum speed at the surface of the fluid at the surface for h = H can be determined as:

$$V_s = k \frac{H^2}{2} \qquad (13)$$

Where, $k = \frac{2V_s}{H^2} \qquad (14)$

Substituting k into Equation (12):

$$V = \frac{hV_s}{H}\left(2 - \frac{h}{H}\right) \qquad (15)$$

The expression of the average velocity of flow can be represented by:

$$V_m = \frac{\int_0^H V \partial h}{H} \qquad (16)$$

The numerator of the second member of

equation (16) is determined as:

$$\int_0^H V dh = V_s \left(\frac{2h^2}{2H} - \frac{h^3}{3h^3}\right) \qquad (17)$$

$$\int_0^H = \tfrac{2}{3}\left(V_s H\right) \qquad (18)$$

$$V_m = \tfrac{2}{3}V_s \qquad (19)$$

Thus, the average speed of flow on an inclined surface is equal to 2/3 the speed of the surface layer of the fluid.

The height at which the speed of the particle is equal to the average speed of flow on an incline plane is determined by equations (15) and (19) as given in Equation (20):

$$\frac{2}{3v_s} = \frac{h'_{vs}}{H}\left(2 - \frac{h'}{H}\right) \qquad (20)$$

After mathematical transformations we get:

$$\frac{h'^2}{H^2} - \frac{2h'}{H} + \frac{2}{3} = 0. \qquad (21)$$

$$h' = \left(1 \pm \frac{\sqrt{3}}{3}\right)H \qquad (22)$$

Solving equation with the minus sign for h < H gives

$$h' = 0.423H. \qquad (23)$$

Equations (22) and (23) state that average velocity of the fluid is equal to the velocity of the elemental layer which is located at a distance 0.423H from the bottom of the sluice.

However, this deduction is only valid for laminar flows and requires a certain adjustments for turbulent flow which occurs on a sluice board. The value of the non-numerical coefficient in Equation (20) can be taken as the following: 1, 5, 4, 45, 51, and 54. Thus, the value of laminar flow is given as 2/3 and transition from laminar to turbulent is between 2/3 – 3/4. On the other hand, turbulent flow values range between 2/8 and 7/8 and values above 7/8 may be obtained for higher values of Reynolds numbers. For instance, the operational regimes of sluice board superficial velocities range between 0.5 – 3.0 m/s, the coefficient in Equation (20) is on average 5/6. Thus, the average speed becomes:

$$V_m = \frac{5}{6}V_s. \qquad (24)$$

The vertical component of the speed of fluid is therefore expressed as a fraction of the average speed of the fluid:

$$u_0 = kV_m, \qquad (25)$$

Where, $k$ is the vertical component of the speed of fluid. Therefore, based on equation (25):

$$u_0 = \frac{5}{6}kV_s \qquad (26)$$

The values of the vertical components of the speed, coefficient $k$ and their corresponding average speeds are shown in Table 1. The data in the table shows that the vertical component of the velocity $u_0$ increases less intensely with small mean velocities than with large velocity values of $V_m$.

**Table 1 The Average Speed and Coefficient, $K$**

| $V_s$ =superficial velocity of fluid, m/s | $V_m = \frac{5}{6}V_s$ | $K$ | $u_0$, m/s | $V_m = \frac{2}{3}$ |
|---|---|---|---|---|
| 0.5 | 0.42 | 0.055 | 2.31 | 1.54 |
| 1.0 | 0.83 | 0.073 | 6.03 | 4.02 |
| 2.0 | 1.67 | 0.088 | 14.63 | 9.75 |
| 3.0 | 2.50 | 0.160 | 40.00 | 26.00 |

**Source: Fomenko (1980)**

## 1.2 Movement of Mineral Particles in Water on an Inclined Plane

Mineral particles transported in slurry on an inclined board move by hopping and rolling. The bouncing of the particles becomes higher when the average velocity of the fluid is relatively high and the diameter of particles is smaller. After the upward movement, they settle at the bottom. The rolling and displacement of particles on sluice board occur simultaneously: they sometimes fall to the bottom and slide whilst hopping, then rise up to determined heights before being dragged by whirlwinds and remain suspended, after which they are carried by the turbulent currents. Spherical particles roll freely on the inclined plane under the condition that the moment of the friction caused by rolling resistance is smaller than the friction produced by force of displacement, hence:

$$R\frac{d}{2} > M_0 \qquad (27)$$

where R is the sliding frictional force;

D is the diameter of particle and $M_0$ is the moment of frictional force;

$$R = \rho N; M_0 = \rho_0 N \ , \qquad (28)$$

where $\rho_0$ is the sliding friction coefficient and $N$ is the normal force on the particle acting at the bottom.

Thus, substituting equation 28 into equation 27;

$$\rho N \frac{d}{2} > \rho_0 N \ , \qquad (29)$$

where $d > \dfrac{2\rho_0}{\rho}$ . $\qquad (30)$

Thus, equation (27) is said to be valid only when the diameter of the particle is two times greater than the quotient of the coefficient of sliding friction and the rolling resistance. According to Fomenko (1980), the movement of a minimum particle on a sluice board (Fig.3) is influenced by forces such as force of gravity, dynamic pressure of flow of water in the direction of movement of the particle, vertical component of the force of inflow directed upwards, the frictional force directed opposite to the direction of the particle and the force from the weight of the particle in water, G. Thus,

$$G = mg_0 \ , \qquad (31)$$

Therefore, the force of dynamic pressure of water acting on the mineral particle is given as:

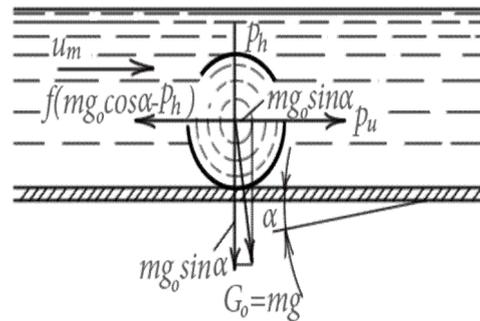$$Pu = \Psi(V_m - V)2d2\Delta \ . \qquad (32)$$

where: $\Psi$ = coefficient of resistance;

$(V_m - V)$ = average velocity of the jet of water;

$V$ = average velocity of the movement of the mineral particle;

$d$ = diameter of the mineral particle;

$\Delta$ = density of the liquid.



**Fig.3 Forces Acting on a Body in the Water Stream Flowing on an Inclined Plane Source: Fomenko (1980)**

### 1.2.1 Determination of the principal parameters of the sluice

Since the drag of mineral particle in water is conditioned mainly by the vertical component of the speed of the fluid, the fundamental parameters which determine the technological indices of the sluice board are the height of riffles, distance between the riffles, the length of the board, and the angle of inclination and productivity.

*Height of riffles*

The determination of the rifle height is also controlled by hydrophysical principles. Bedload motion in a river channel can be passive and active. The alternate zones of erosion and accumulation is influenced by flow depths and velocities. (Sidorchuck, 2015). Alekseevski and Sidochurk (2017) explain sediment deposition and morphology of river beds showing the length and height of sediment transport and the relationship between flow velocity and depths. However, on the sluice board the height of the riffles assures the retention of the mineral particle, and depends on the height of suspension of the said particle and is determined by:

$$h = \frac{u_0 - u}{u}c \ , \qquad (33)$$

where, $u_0 = kV_m$ ,

$$h = (u_0 - u)\frac{c}{u} = (kV_m - u)\frac{c}{u} , \qquad (34)$$

$$V_m = V_s .$$

where, $V_s$ is the maximum velocity of the flow at the surface water, $c$ is the distance from the bottom at which the vertical component of speed reduces twice (See Table 2). According to Goncharov (1938):

$$c = 0.14\Delta^{0.2}H^{0.6} , \qquad (35)$$

Where, $\Delta$ = the roughness of the bottom of the board;

$H$ = the height of the fluid.

The factor $(kV_m - u)$ of Equation (34) is the speed at which the particle starts to suspend in the fluid.

In this case, the local speeds initially have insufficient values for the drag of the particles and therefore they only hop on the surface of the board. The instantaneous speed values acquired makes it possible to lift the particles from the bottom to a certain height. The speed $u$ which acts on the particle at the bottom is approximately equal to the settling speed limit of the particle $V_0$ in water. Therefore, when the particles start hopping on the surface, $u$ is expressed as:

$$u = V_0 = kV_s \qquad (36)$$

Thus the expression which determines the condition for the suspension of the particle takes the form:

$$u_0 - u = k(V_m - V_s) \qquad (37)$$

Thus, substituting this into equation (17),

$$\int_0^H Vdh = V_s\left(\frac{2h^2}{2H} - \frac{h^3}{3h^3}\right)$$

$$h = \frac{k(V_m - V_s)}{U}c \qquad (38)$$

Therefore, for particles of defined size, the uniform settling speed in water is equal to $V_0$ and the height of the suspension is given as:

$$h = \frac{k(V_m - V_s)}{V}c \qquad (39)$$

or better

$$h = \frac{k(u_0 - V_s)}{V_0}c \qquad (40)$$

**Table 2 Roughness Values and the Value of c**

| A      Background character | Roughness height Δ, cm | Value of c, cm |
|---|---|---|
| Background tables planed and carefully adjusted or a very flat metal surface | 0.05 | 12.22 |
| Planed fund tables or iron cross | 0.05 | 14.44 |
| Planed fund tables or iron cross with small inlaid | 0.1 – 0.2 | 16.56 |
| Not sawed board's background covered with rubber mats | 0.2 – 0.5 | 19.91 |
| Background of fine material covered with sludge | 0.5 – 1.0 | 36.24 |
| Covered background of grains of sand and rock without noticeable protrusions | 1.0 – 2.0 | 41.64 |
| Covered background fine stone and rock | 2.0 – 4.0 | 47.83 |
| Background covered with thick stone or rock | 4.0 – 8.0 | 54.94 |

**Source: Fomenko (1980)**

The height of the riffles to trap particles of gold ($h_r$) should be greater than the suspension height of the particle, but should be lesser than the suspension height of the lighter particles:

$$h_t < h_r < h_{lighter}$$

The height of the suspension of particles of gold and that of different sizes on sluices can be calculated using Equation (39).

*Riffle spacing*

The space between the riffles is equivalent to the wavelength at the beginning of the thinning. This distance can be calculate using the following formula:

$$l = \frac{v_d - v_m}{v_f} h$$

where,

$h$ : The riffle height;

$v_m$ : Average speed of flow which forms good current waves;

$v_d$ : Average speed of flow at which the current waves disappear; and

$v_f$ : Average speed for flow at which the sands stop moving.

For long boards the following empirical values can be estimated:

$$v_m = 1.67 m/s \; ;$$

$$v_d = 2.2 m/s \; ; \text{ and}$$

$$v_f = 0.25 m/s$$

For shorter boards the following empirical values of speed can be used:

$$v_m = 0.83 m/s \; ;$$

$$v_d = 1.3 m/s \; ; \text{ and}$$

$$v_f = 0.25 m/s$$

## 2 Resources and Methods Used

### 2.1 Materials

About 50 kg of sluice board tailings was obtained from "Peace School" small scale mine near the University of Mines and Technology (UMaT). The sample was a highly oxidized gold ore which makes it amenable to gravity concentration. The material was screened, and the particle size distribution was recorded as 90% passing 250 μm which makes it suitable for sluicing.

### 2.2 Ore Testing

Panning was done by taking a representative sample of 500 g, to test for the presence of free gold in the tailings material. However, no free gold was detected in the head grade.

### 2.3 Head Grade Determination

Further test was conducted by taking another sample of the tailings material and digested with aqua regia, and heated for 10 minutes. The filtrate was analysed by the Atomic Absorption Spectrometer. The grade in the sample was recorded as 3.8 g/t. This gave information about the presence of gold in the tailings sample and the need for the experiment.

### 2.4 Construction of the Sluice Board

The sluice board was constructed using a "Wawa" board with a length of 2 m. The riffles were made of palm fronds shaped into uniform height of 1.0 cm (H1) from the base of the sluice board. The height of the riffle was determined using Equation (34), where c = 19.91 cm (for the roughness of an unplaned surface). The riffles were equally spaced and varied at distances of 5 cm, 10 cm, 15 cm and 20 cm from the discharge end of the flume for each sluicing operation. The height of the riffles was then changed from 0.5 (H2) to 1.5 cm (H3) respectively to determine the effect of the height of the riffles on the concentration of the material. A Corduroy material was thereafter used as the matting. To ensure effective cleaning out of the riffles, the matting was cut into a size of 310 mm by 600 mm. The sluice board was inclined at an angle of 14 – 15º as shown in Fig. 4.



**Fig 4 Sluice Board with (A) Riffles and (B) Matting**

### 2.5 Sluicing

Sluicing was carried out at different riffle heights ( between 0.5 and 0.92 cm) with spacing of 5, 10, 15 and 20 cm. Sluicing was done with constant water flow rate of 0.15 m³/s. The feed to the sluice board was pulped before the pre-concentration process. A bowl was placed just beneath the discharge end of the sluice board to collect the tailings. Each concentrate and tailings obtained after the sluicing was decanted and dried as shown in Fig.5. Each

"dry-cake" was stored in a sample bag and labelled as: CH15, CH110, CH115, and CH120 for concentrate obtained from sluicing at H1 (0.92) with spacing of 5, 10, 15 and 20 cm. The tailings were labelled as TH15, TH110, TH115, and TH120. The sluicing at H2 (0.5 cm) was tagged as CH25, CH210, CH215, and CH220, and TH25, TH210, TH15, TH220. The following samples were taken for sluicing at H3: CH35, CH310, CH315, CH320, TH35, TH310, TH315 and TH320.



**Fig. 5 (A) Sluicing Set-Up and (B) Labelled Samples of Concentrate and Tailings**

## 2.6 Acid Digestion

One of the reagents that dissolves gold is a mixture of nitric acid and hydrochloric acid in a volumetric ratio of 1:3. Samples of 20 g and 50 g of concentrate and tailings respectively, were taken from the "dry cake" using the Coning and Quartering sampling techniques. They were digested for 10 minutes in a Pyrex glass at a high temperature with a mixture of $HNO_3$ and $HCl$ (30%concentration) acid at a ratio of 1:3.

After that, each sample was allowed to cool down for 10 minutes, and then filtered. A total of 24 containers of filtrate with measured volumes were labelled (1, 2, 3….24) for AAS analysis (Fig.6).



**Fig. 6 Digestion of Sample (A) and Labelled Containers with Filtrate Ready for AAS Analysis (B)**

## 2.7 Size Distribution of Head and Tailings

Particle size analysis was conducted to determine how the particles were distributed among the sample that recorded the highest percentage of gold. Four sieves with different aperture sizes of 450 μm, 250 μm, 180 μm and 125μm were selected using Tyler series.

# 3 Results and Discussion

## 3.1 Results on the suspension height of the gold particle

Based on Equation (34), the suspension height of the gold particles of the operating regimes of the sluice board (0.5 – 3.0 m/s superficial velocity) was determined and presented in the Table 3.

**Table 3 Suspension Height of Gold Particle at Various Superficial Velocities C = 19.91 cm**

| $v_s$ (m/s) | $v_m$ (m/s) | k | $u_0$ (m/s) | $v_m$ (m/s) | h (cm) |
|---|---|---|---|---|---|
| 0.5 | 0.42 | 0.055 | 2.29 | 1.53 | 0.9 |
| 1.0 | 0.83 | 0.073 | 6.08 | 4.06 | 1.2 |
| 2.0 | 1.67 | 0.088 | 14.67 | 9.78 | 1.5 |
| 3.0 | 2.5 | 0.160 | 40.00 | 26.67 | 2.9 |

## 3.2 Results of Sluicing

The results of sluicing taking into consideration the various suspension heights of gold particles of various operational regimes of the sluice board are shown in Fig. 7.
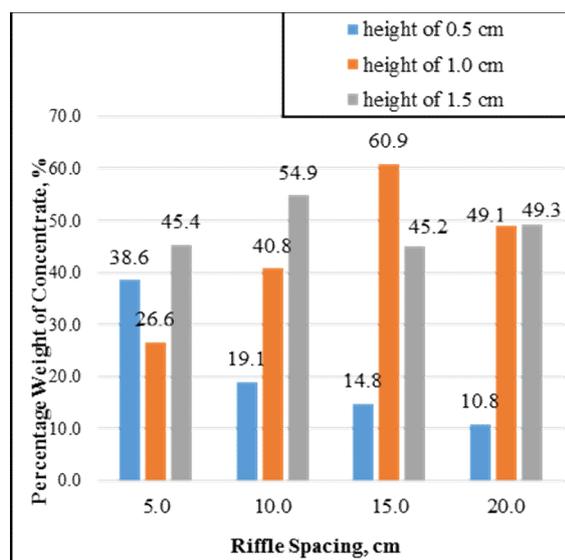
From Fig.7, it is realised that, the percentage weight of concentrate of the sluice-board at a riffle

height of 1.0 cm with 5 cm spacing increased. However, beyond 15 cm of spacing, there was a decrease in percentage weight of concentrate. This is because, as the riffles spacing become too close to each other, the vortex of the flow of the slurry becomes impeded such that the heavy particles (possible gold particles) overflow the riffles instead of being trapped by the riffles. Under these conditions, the backside of the downstream riffle will begin to collect material and the bottom of the vortex will rise off the mat.

However, when the riffles were spaced far apart, the flow of the slurry downstream onto the riffle is not overturned and therefore continues to flow up and over the next riffle. These conditions, then cause most of the valuable particles to end up in the tailings, hence reducing the weight of the material on the sluice board.

Furthermore, the weight of the concentrate at height 0.5 cm decreased to increasing riffle spacing. This is because, the height of the riffles was lower than the suspension height of the mineral of interest (and possibly the gangue minerals) and therefore greater percentage ended up in the tailings.

The weight of the concentrate at 1.5 cm riffle height might have not followed a particular pattern of increasing riffle spacing, however, it was observed that there was not much difference between the weight of the concentrates and the weight of the tailings. This was due to the higher height of the riffles; both the heavy and light matter were trapped behind the riffles and reached the apex (of the riffles) very quickly. However, as washing on the board was in progress, the materials that had already been trapped by the riffles moved to the bottom of the riffles with most ending up in the tailings.



**Fig. 7 Percentage Weight of Concentrate at Various Riffle Heights and Spacing**

From Fig.8, it can be observed that, the percentage of gold recovered by the sluice-board at a height of 1.0 cm increased towards a riffle spacing of 15 cm, and decreased at a spacing of 20 cm. This was because the height of the riffles was greater than the suspension height of the heavy metal, but lesser than that of the lighter metals. However, when the riffles were too close, most of the heavy metals rolled over the riffles due to the accumulation of the lighter materials behind the riffles. Flow in this instance is transitional (laminar to turbulence) instead of turbulent which could have kept the gold particle in suspension. Recovery increased steadily from a spacing of 10 cm to 15 cm (where the highest percentage of gold, 85.4% was recorded) but decreased at 20 cm spacing.
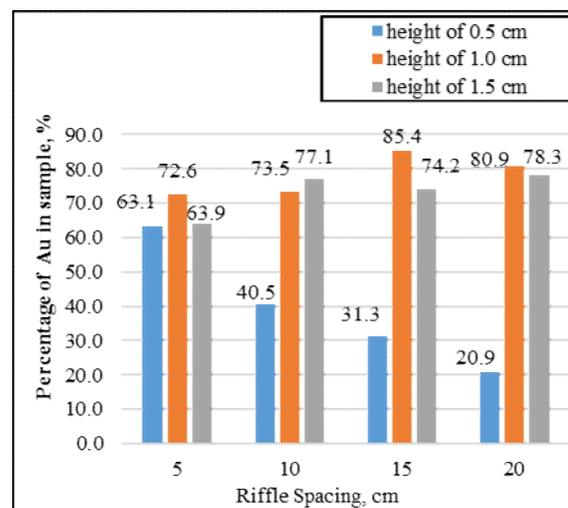


**Fig. 8 Percentage of Gold in Concentrate Obtained at Various Riffle Heights and Spacing**

The percentage of gold recovered by the board at a riffle height of 0.5 cm compared to that of 1.0 cm riffle height was less because the height of the riffles was lower than the suspension height of the gold particles and therefore most of the gold moved into the tailings. The percentage of gold recovered by the board at the riffle height of 1.5 cm was relatively higher compared to that of the 0.5 cm height. Nonetheless, recovery was inconsistent with spacing because the riffle height was too high for concentrating feed of such particle size. Riffle height of 1.5 cm will be best for concentrating coarser feed particle.

## 3.3 Particle Size Distribution

The similarity between the size distribution graphs (Figs. 9 and 10) of the concentrate and the tailings evidences the uniformity of the size of the material used for sluicing. A closed sized material enhances the effects of density on gravity concentration and reduces the effects of size. Classified particles reduce the free settling particles of different

specific gravities that fall at the same time. Also since the separation is done in hindered settling medium, the effect of density will also be more pronounced.
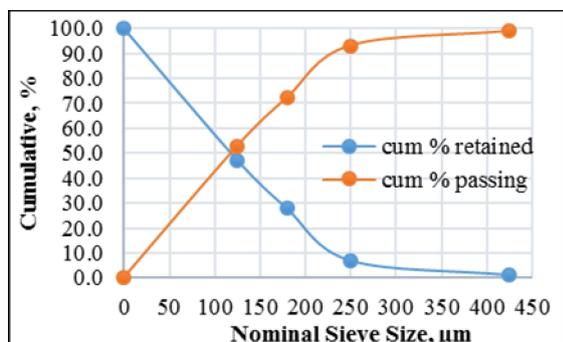


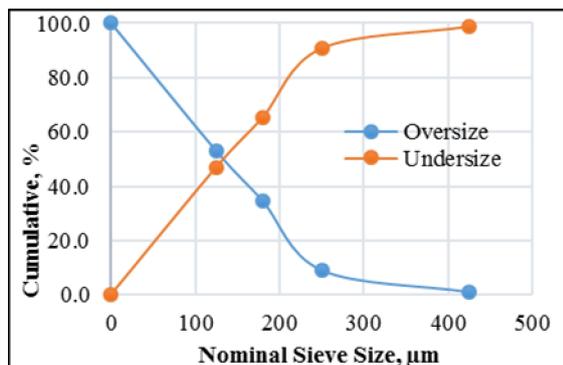**Fig.9 Cumulative Percent against Nominal Sieve Size for Sample CH115**



**Fig.10 Cumulative Percent against Nominal Sieve Size for Sample TH115**

## 4 Conclusions and Recommendations

### 4.1 Conclusions

The optimum operational parameters for sluice board used in free milling or alluvial gold recovery are as follows:

    (i)   At a riffle height and spacing of 1.0 cm and 15 cm respectively, appreciable percentage of gold was recovered for the indicated velocities of flow and the spacing;

    (ii)  Although free gold was not detected, the experimental recovery results show the gold was present in the black concentrate; and

    (iii) Highest recovery of the board (85.4%) was at 1.0 cm height and 15 cm riffle spacing.

### 4.2 Recommendations

    (i)   Small-scale miners who use sluice boards should be advised on the importance of riffles;

    (ii)  Further study should be conducted on the other operational parameters to aid further increased recovery;

    (iii) Further test work should be conducted to know the distribution of gold particles in the various concentrates and tailings samples.

## References

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