

Siltation of Ore Particles in Leaching Tanks: Causative Factors and Mitigation Measures*

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Abstract

Siltation involves the accumulation of sediment over a considerable period of time and this may occur in closed systems like leaching tanks. Most mining companies in Ghana experience siltation problems during leaching of gold ore. This paper examines the potential causes and possible mitigation measures of siltation. Particle size analysis, slurry settling rate tests and agitation efficiency analysis were used in identifying causative factors of siltation while deflocculation test and grind analysis were conducted to ascertain mitigation measures. Results from the study indicated that, high settling velocity of particles, inefficient milling and classification, poor slurry agitation and particle flocculation were the major causative factors leading to siltation. Size analysis results revealed P_{67} of 106 μm instead of P_{80} of 106 μm , a situation which affects particle suspension by agitators leading to siltation. This study therefore suggests that increase in milling residence time and particle deflocculation are potential remediation measures for curbing siltation. Extended grinding of ball mill feed resulted in 94% passing 106 μm while settling velocity was reduced by 71% after deflocculant addition at 1000 ppm.

Keywords: Siltation, Deflocculation, Settling Velocity, Grinding

1 Introduction

Most mineral extraction operations begin with a comminution process to liberate the mineral of interest. Comminution is the progressive reduction in the size of an ore to a suitable size range to liberate the mineral of interest from the worthless gangue material or shorten the travel distance of reagents during leaching. In a typical gold extraction plant where agitation leaching is employed, comminution may be accomplished stepwise through a circuit made of a primary crusher, Semi Autogenous Grinding (SAG) mill and ball mills. The SAG and ball mills generally have independent cyclones to classify their products (Wills, 2006; Amankwah and Ofori-Sarpong, 2011).

In this era of low grade ores and low metal price regimes, most plants now operate on high tonnage and leaching is conducted at pulp densities in excess of 50% solids instead of conventional values between 40% and 45%. Thus, the classifier overflow material is prepared for leaching by passing it through a thickener to obtain the appropriate feed density in excess of 50% solids. The thickening process requires the use of flocculants and this chemical that assists in thickening may have a carry-over effect and also

cause repeated settling or siltation during leaching in tanks.

The presence of coarse materials in leaching circuits also affects particle suspension by agitators due to the smaller surface area and higher drag forces of such particles in a turbulent flow regime. These effects cause them to gravitate to the bottom of containing vessels as a result of gravitational, centrifugal or any external force acting on the particle and thus, enhance sedimentation (Walsh, 1988; Concha, 2009). The accumulation of such sediments over a considerable period of time leads to siltation, a situation which is faced by most mining and mineral processing companies.

Siltation leads to the formation of a stationary bed at the bottom of the leach tank over a considerable period of time and is a major problem in agitation tanks, where particles intended for suspension get settled based on several factors. This process reduces the effective volume of leaching tanks available for leaching which also reduces the tonnage of ore that can be processed within a given residence time. Coarse gold particles present in such tanks gravitate to the bottom due to their high drag force and get locked up in the silt material. Coarse gold locked up in silt materials in some gold processing plants are as high as 53 g/t (Konadu *et al.*, 2014). In this research, causative

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factors for siltation of tanks in the Carbon-in-Leach Plant of Gold Fields Ghana Ltd at Tarkwa were investigated. The mitigation measures to siltation are also proposed.

2 Resources and Methods Used

2.1 Materials

The samples used in this study were Semi Autogeneous Grinding (SAG) mill cyclone overflow product, ball mill feed, ball mill cyclone overflow product, pre-leach thickener feed, leach feed and silt material obtained from the mineral processing plant of Gold Fields Ghana Limited (GFGL). The silt samples were obtained from a 17.1 x 15.8 m (height x diameter) drained leaching tank.

2.2 Methods

Screen analysis, settling rate test and agitator efficiency analysis were carried out on the metallurgical plant whiles grind analysis and deflocculation test were carried out in the Minerals Engineering laboratory of University of Mines and Technology.

2.2.1 Screen Analysis

Wet screening was conducted on four randomly sampled silt material to access the particle size distribution of the silt materials. The nest of screens used were built according to the Tyler series with 6700 μm as the coarsest screen aperture size and 106 μm , the lowest. Ball mill cyclone overflow sample, composited for a period of two weeks, was wet-screened using a 106 μm screen to determine the percentage passing 106 μm .

2.2.2 Settling Rate Test

Settling rate tests were conducted on the SAG and ball mill cyclone overflow samples and the thickener feed in a graduated 1000-ml measuring cylinder for a period of 40 minutes by monitoring the change in slurry boundary at 30 seconds intervals. The results were plotted graphically and equation of the curve generated to extend the time on the settling curve using exponential decay curves. The experiment was run in triplicate. Settling velocities of the samples together with a standard sample milled to 80% passing 106 μm were determined.

2.2.3 Agitation Efficiency Analysis

Measurements were taken on a fresh agitator blade and a worn out blade using an engineering tape. Design measurement of the leaching tank (diameter, height, freeboard and agitator off-bottom

distance) was obtained and inference drawn from them. Visual observation was conducted in a drained tank containing silt material.

2.2.4 Grind Analysis

Ball mill feed samples from the plant which comprises of the SAG mill cyclone underflow and the ball mill cyclone underflow were milled at 65% pulp with reference to the milling pulp density of the processing plant, for 5, 10, 15 and 20 minutes. Initial percent passing 106 μm of the ball mill feed sample was estimated via wet screening. Final milled products obtained were wet screened and the percentage passing 106 μm screen aperture size, estimated.

2.2.5 Deflocculation Test

One kilogram dry mass of leach feed sample having particle size distribution of (+ 220 μm -75 μm) was pulped to 56% to obtain material with pulp density similar to that of the metallurgical plant. Settling rate tests were conducted on the sample for 60 minutes without deflocculant addition and the fall in slurry boundary noted every 2 minutes. This was to serve as a control for the subsequent experiment, which was replicated using caustic as a deflocculant at different concentrations for 60 minutes and the fall in slurry boundary monitored for every 2 minutes. The equation of the curve was generated and time extended to plot settling curves using exponential decay curves.

3 Results and Discussion

3.1 Screen Analysis of Silt

The particle size distribution of the silt materials was investigated and Fig. 1 shows the cumulative percentage passing for the various screen sizes. This reflects the various size ranges of particles in the silt material, and the coarse nature gives a clear indication of the poor grinding and classification processes. The 80% passing size of the silt material was estimated to be 1700 μm which is far higher than the design size range (P_{80} of 106 μm) for leaching. Indeed, 94% of the silt material had particle size range above the design size of 106 μm . Coarser particle sizes impact adversely on particle suspension by agitators due to the high drag forces of such particles which gives them high settling velocities, thus leading to siltation (Walsh, 1988).

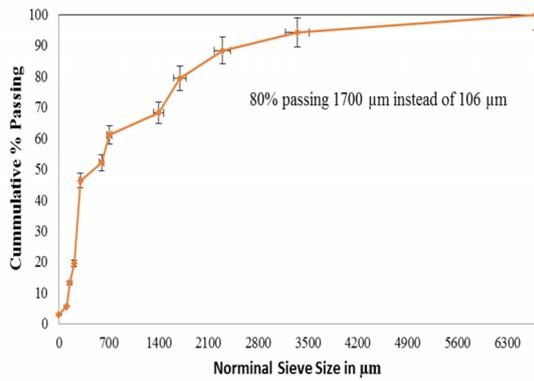


Fig. 1 Screen Analysis of Silt Material

3.2 Screen Analysis of Ball Mill Cyclone Overflow

Following a 14-day campaign, the percentage of material passing 106 µm for the ball mill cyclone overflow, as shown in Fig. 2, indicates that 67% of the feed particles had sizes less than 106 µm (P_{67} of 106 µm) instead of the design size of 80% passing 106 µm (P_{80} 106 µm). According to Fig. 2, only two (2) out of the fourteen (14) samples were within the design leach feed size. This situation will put undue pressure on the agitators, hence creating suspension inefficiencies and enhancing feed particle siltation.

The coarse nature of the cyclone overflow may be ascribed to several factors including short residence time of feed materials in the ball mill as a result of the dwindling gold grade and/or gold prices which compels management to resort to processing high tonnage with constant residence time of feed in the mill to meet targeted tonnages. This in effect produces coarse mill products (Konadu *et al.*, 2014).

Other contributing factors in the grinding circuit to the coarse cyclone overflow include inefficient classification by cyclones due to high tonnages and cyclone pressures which at some times exceed the design plant value of (120 – 130) kPa. The state of mill liners may also affect grinding in cases of severe wear.

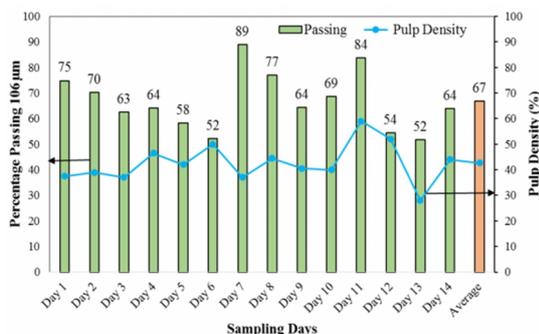


Fig. 2 Screen Analysis of Ball Mill Cyclone Overflow

3.3 Settling Rate Test

Fig. 3 (A to D) presents the effect of settling velocity on particle siltation in various systems. In all cases, settling velocity was high compared with a standard feed particle size with P_{80} of 106 µm. Settling velocity of the Ball Mill Cyclone Overflow (BMCO) was the highest followed by the Thickener Feed (TF) and the Sag Mill Cyclone Overflow (SMCO). The average of all the settling velocities of particles in these systems was high compared with the standard settling velocity of feed particle with P_{80} of 106 µm. High settling velocity of the BMCO is as a result of its coarse nature, having an average of P_{67} of 106 µm. The coarse nature gives it higher drag force which enhances settling (Walsh, 1988). The SMCO was expected to exhibit low settling velocity, but it turned out to be high irrespective of its fine particle size of 94% passing 106 µm from a data received from the plant. This can be attributed to high pH values observed at the milling and classification unit, which introduces negative charge densities on the suspended particles nullifying the repulsive forces and causing them to sediment faster (Ersoy, 2004). The pH values observed at the milling and classification units were above 11.5 to as high as 13.75, which enhanced settling as the lime used in pH modification aids settling when in excess. The TF which is a blend of the BMCO and SMCO had a higher settling velocity as well. Feed from the TF undergoes flocculation which further increases its settling velocity as a result of the flocculants creating polymer bonds between feed particles and thus producing lumps with higher drag forces which causes fines to also settle. Such material, when forwarded to the leaching tanks, sediments faster leading to siltation due to some agitation inefficiencies.

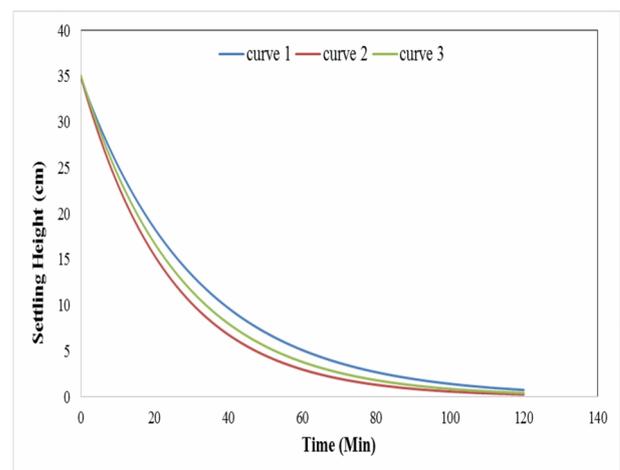


Fig. 3 (A) Ball Mill Cyclone Overflow Settling Curve (BMCO). Curves 1, 2 and 3 are Results of Replicates

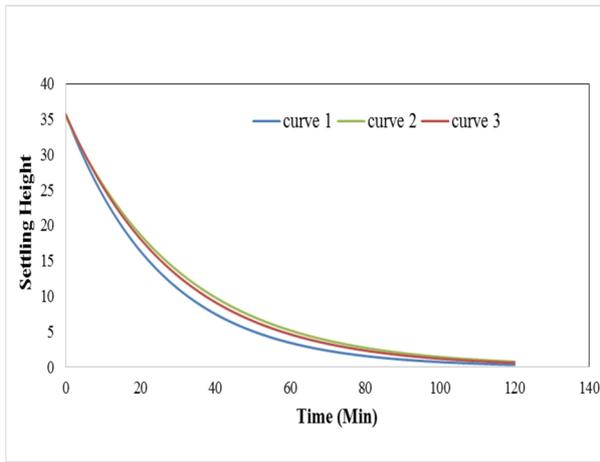


Fig. 3 (B) SAG Mill Cyclone Overflow Settling Curve (SMCO). Curves 1, 2 and 3 are Results of Replicates

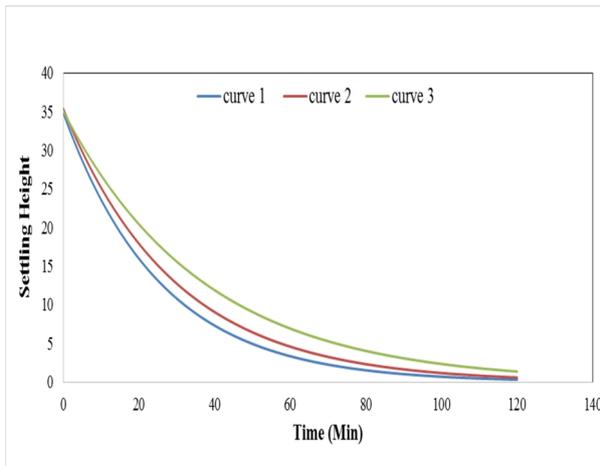


Fig. 3 (C) Thickener Feed Settling Curve. Curves 1, 2 and 3 are Results of Replicates

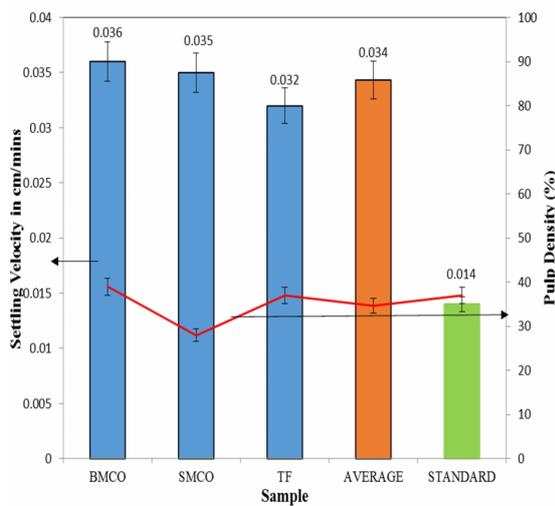


Fig. 3 (D) Average Settling Velocities of Particles in Various Systems

3.4 Agitation Efficiency Analyses

3.4.1 Measurements

Analysis of design measurements obtained from the plant indicated that, the off-bottom distance of the agitator was 19 feet (5.8 m) as indicated in Fig 4. Other measurements recorded are detailed in Table 4.2. Literature reveals that for maximum off-bottom suspension of solids, an impeller location of 1/3 the impeller diameter blade may be satisfactory (Anon, 2015). However, the off-bottom distance in the leaching tank exceeds that in literature. The diameter of the impeller blade was 5.2 m and from literature its off-bottom was supposed to be 1.7 m however, the off-bottom was 5.8 m which is three times higher and hence affects mixing efficiency. By reducing distribution of radial and axial forces introduced into the slurry by agitation, some areas are left unmixed. Feed particles with higher settling velocities located below the required off-bottom distance region are prone to settling leading to siltation.

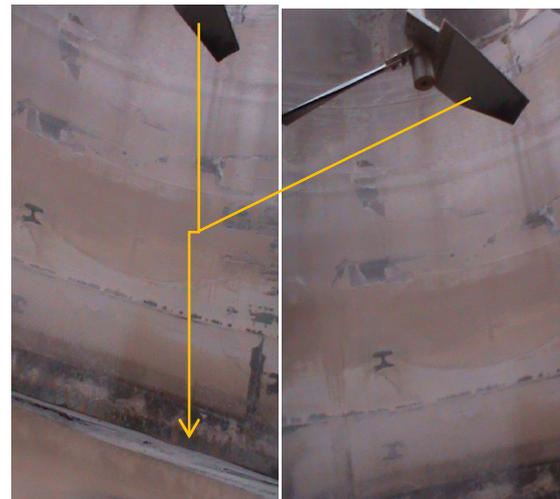


Fig 4 Agitator Off- Bottom

Table 4.2 Measurements taken from the Plant

PARAMETERS	MEASUREMENT (m)
off-bottom distance of agitator	5.8
diameter of leach tank	15.8
height of leach tank	17.1
freeboard of leach tank	0.6
length of fresh agitator blade	2.6
length of worn out agitator blade	2.3
perimeter of fresh agitator blade	6.6
perimeter of worn out agitator blade	5.0
% wear of agitator blade	24.3

Agitators tend to wear out with time due to friction between impeller blades and feed material as well as the presence of reagents and chemicals in the tank. Wearing of agitators affects mixing efficiency, by reducing total perimeter covered by the agitator. Such a situation favors siltation since the agitator's efficiency is reduced.

3.4.2 Observation

Visual observation in a drained tank showed that agitators encounter mechanical failure such as displacement (Fig. 5). Displacement of agitator blades highly affects mixing by reducing diffusion of radial and axial forces through the slurry causing feed particles to sediment leading to siltation. In Fig. 5, the displacement was on the lower impeller blade which led to a high silt build up in the tank; up to about 3 m.



Fig. 5 Mechanical Failure of an Agitator Blade

3.5 Grind Analysis

Fig. 6 indicates the effect of grinding residence time on mill product. The initial percentage passing 106 μm of the circulating load at time zero was 13% and from the results it was seen to be increasing with increasing grinding time. The trend is similar to that presented by Song *et al* (2012). With increasing residence time, the feed in the mill achieves maximum abrasion and impact from coarser feeds, steel balls and liners to cause particle size reduction which enhances particle breakdown. The required time for attaining 80% passing 106 μm was estimated by interpolating between 10 minutes and 15 minutes and it was found to be 12 minutes, 22 seconds. Increasing grinding time would produce finer mill products with lower drag forces which would enhance particle suspension at an optimum pH by the agitator in the absence of mechanical failure.

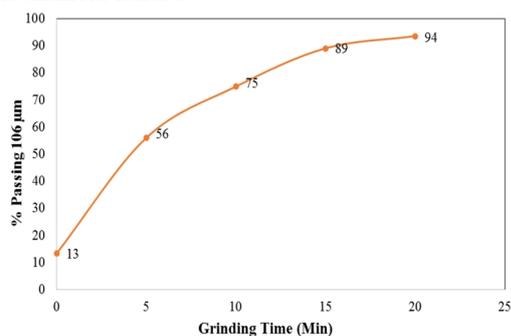


Fig. 6 Grind Analysis of Mill Feed

3.6 Deflocculation Test

Figure 7 (A and B) shows the drop in settling velocities of the leach feed upon addition of caustic as a deflocculant. This is as a result of the deflocculant creating a steric repulsion between the particles and also breaking polymer bonds between flocculants and feed particles. The deflocculant increases zeta potential of the particles, decreasing the attractive forces between the particles and in effect increasing repulsive forces. This is as a result of the presence of sodium ion in the deflocculant. It increases the electrical double layer between particles by being attracted by the negatively charged feed particle and in effect creating repulsion between neighbouring particles thus keeping them in a state of suspension (Larsson *et al.*, 2012; Zchimmer and Schwarz, 2009). Settling velocity was seen to reduce by 71% at 1000 ppm of caustic with reduction decreasing as concentration increased. At 10000 ppm, settling velocity reduced by 14% as a result of higher percent solids and deflocculant concentration leading to overlapping and superimposition of zeta potential of neighbouring particles (Zchimmer and Schwarz, 2009).

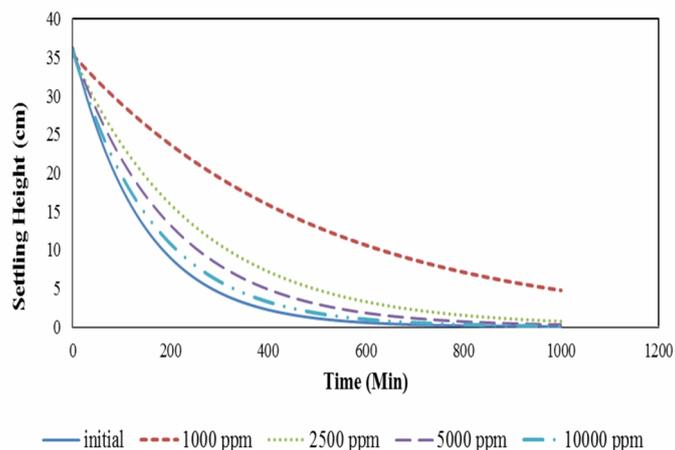


Fig 7 (A) Settling Curves obtained after Deflocculation Test

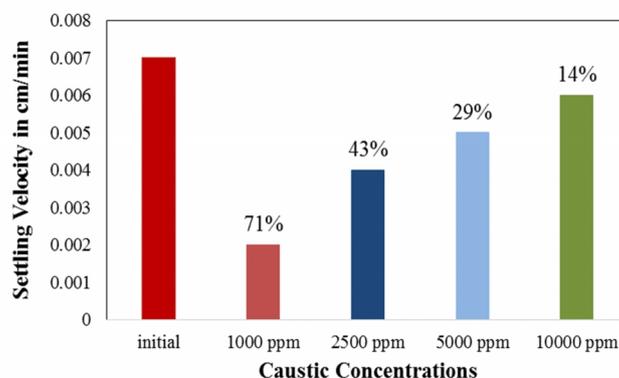


Fig 7 (B) Reduction in Settling Velocity with Deflocculant Addition

4 Conclusion

Factors leading to particle siltation in gold leaching tanks and corresponding mitigation measures were investigated. It is comprehensible from the investigations that inefficient milling and classification, high settling velocities and agitation inefficiencies were the major factors leading to siltation. The result showed that the average percentage passing size for the ball mill cyclone overflow was 67% passing 106 μm instead of 80% passing. The average settling velocity of the ore was also estimated to be 5.67×10^{-6} m/s. The efficiency of the agitator was also assessed with reference to its off-bottom distance which was 5.8 m, three times higher than an expected distance of 1.7 m. Mechanical failures and design measurements also contributed to the inefficiency of the agitator. However a drastic decrease in settling velocity was accomplished when caustic was used as a deflocculant at 1000 ppm. The results of this study therefore reveal that deflocculation and finer grinding are options for mitigating siltation in gold leaching tanks considering its causative factors. The authors thus propose the use of finer grinding and deflocculation as strategies to remediate siltation in gold mineral processing plants.

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