

Settling Characteristics of Iron Ore Slurry under Different Physicochemical Conditions

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Abstract: Efficient solid–liquid separation of iron ore tailings is an important aspect of mineral processing industries due to its direct influence on thickening, dewatering, water recovery, and tailings management. The present investigation evaluates the settling characteristics of iron ore slurry obtained from Bolani tailings under different operational conditions such as variation in solid concentration, pH modification, lime addition, and flocculant dosage. Experimental studies were conducted using graduated settling cylinders at solid concentrations of 5%, 10%, 15%, and 20%. The effect of acidic and alkaline environments was studied using hydrochloric acid (HCl) and sodium hydroxide (NaOH), respectively, while lime and polyacrylamide-based flocculants were used to enhance settling performance. The results revealed that settling velocity increased significantly with decreasing solid concentration due to reduced particle interference and lower slurry viscosity. Acidic conditions promoted faster settling compared to alkaline conditions because of improved particle agglomeration resulting from charge neutralization. Addition of lime further enhanced settling by increasing alkalinity and improving interparticle attraction. Among all conditions investigated, the use of polyacrylamide flocculant showed the highest settling efficiency, producing rapid sedimentation and clearer supernatant liquid owing to effective floc formation through polymer bridging mechanisms. The study demonstrates that settling behaviour of iron ore slurry is strongly dependent on pH, solids concentration, and flocculant dosage. The generated experimental data can be effectively utilized for the design and optimization of thickeners and dewatering systems in mineral processing industries.

Keywords— Iron ore slurry, Settling characteristics, Flocculation, Thickening, Dewatering, Polyacrylamide, Tailings management.

1. Introduction

Iron ore is one of the most important raw materials used in the production of steel and plays a vital role in global industrial development. During beneficiation and mineral processing operations, a substantial quantity of fine tailings and slurry is generated, which creates serious challenges in terms of dewatering, disposal, and environmental management. Efficient settling and solid–liquid separation of these tailings are therefore essential for improving water recovery, reducing environmental impact, and enhancing process efficiency [1]. Settling is a gravity-driven separation process in which suspended particles move downward through a liquid medium due to density differences between the solid and liquid phases. The settling behaviour of iron ore slurry depends on several factors including particle size distribution, particle concentration, pH, surface chemistry, viscosity of the medium, and the presence of chemical additives such as flocculants. Fine and ultrafine particles generally exhibit poor settling characteristics because of electrostatic repulsion and high surface area effects.

In mineral processing industries, settling operations are commonly carried out using thickeners and clarifiers. The performance of these units depends strongly on the settling rate of the slurry and the effectiveness of flocculation mechanisms. Flocculants, particularly high molecular weight polymers such as polyacrylamide, are widely employed to improve particle aggregation and enhance sedimentation rates. Previous investigations have reported that pH control and

flocculant dosage significantly influence settling kinetics and rheological behaviour of mineral suspensions [2]. However, the combined influence of solids concentration, pH variation, lime addition, and flocculant dosage on iron ore slurry settling behaviour requires further experimental analysis. The present work aims to investigate the settling characteristics of iron ore slurry obtained from Bolani tailings under varying physicochemical conditions. The generated data provide useful insights for improving dewatering efficiency and optimizing thickener operation in mineral processing industries [3]. The study aims to investigate the settling characteristics of iron ore slurry at different solid concentrations and evaluate the effect of pH variation on its settling behaviour under both acidic and alkaline conditions. It further focuses on studying the influence of lime addition on sedimentation performance and analyzing the effectiveness of polyacrylamide (PAM) as a flocculant for enhancing slurry settling. The experimental results will be used to generate reliable data that can support thickener design, process optimization, and effective tailings management in iron ore processing applications.

2. Literature Review

Several researchers have investigated the settling and dewatering behaviour of iron ore tailings and mineral suspensions. Dash et al. reported that adsorption of flocculants significantly enhances dewatering efficiency by improving aggregation of fine particles and increasing settling velocity. Eswaraiah et al. studied ultrafine iron ore slimes and observed that particle size and solids concentration strongly affect sedimentation characteristics. Krishna et al. examined the rheological behaviour of iron ore tailings and demonstrated that flocculant addition alters slurry viscosity and improves settling performance. Their work emphasized the importance of rheological characterization in thickener design and tailings transport [4]. Natural and synthetic flocculants have also been extensively studied for mineral processing applications. Bio-based polymers and microbial exopolymers have gained attention due to their environmental compatibility and high flocculation efficiency. Czemińska et al. investigated microbial exopolymers and reported promising flocculating properties suitable for water treatment and mineral separation applications [5]. Studies related to interfacial chemistry have further shown that pH adjustment and surface charge modification play a critical role in particle aggregation. Under acidic conditions, electrostatic repulsion between particles decreases, resulting in improved sedimentation. Lime addition has also been found to enhance settling by increasing alkalinity and facilitating particle bridging. Although considerable progress has been made in understanding settling phenomena, limited studies are available on the combined effect of solids concentration, pH modification, lime dosage, and flocculant concentration under laboratory settling conditions. Therefore, the present study attempts to bridge this gap through systematic experimental analysis.

3. Experimental Methodology

Iron ore tailing slurry obtained from Bolani mines was used for the experimental investigation. Hydrochloric acid (HCl), sodium hydroxide (NaOH), lime $[\text{Ca}(\text{OH})_2]$, and polyacrylamide-based flocculant were used as chemical additives. The slurry samples were prepared at different solid concentrations of 5%, 10%, 15%, and 20%. Each sample was prepared in a 250 mL graduated cylinder, and the pH of the original slurry was maintained around neutral conditions.

Settling experiments were carried out using a graduated measuring cylinder of 1 L capacity. The interface height between the clear liquid and settling solids was measured at regular time intervals. The experimental conditions were investigated to evaluate the settling behaviour of iron ore slurry under different operating conditions. The study included settling tests at different solid concentrations, followed by an assessment of the effect of acidic and alkaline media using hydrochloric acid (HCl) and sodium hydroxide (NaOH), respectively. The influence of lime addition on the sedimentation performance was also examined. In addition, the effectiveness of polyacrylamide (PAM) as a flocculant was evaluated at different dosages to determine its impact on slurry settling and sedimentation efficiency. Lime was added to the slurry at a dosage equivalent to 30 g/ton of slurry solids. The prepared lime suspension was mixed thoroughly with the slurry before settling analysis. Polyacrylamide flocculant was prepared using distilled water and added at dosages corresponding to 30 g/ton, 50 g/ton, and 70 g/ton. The slurry was mixed uniformly and allowed to settle under static conditions.

4. Results and Discussion

The settling characteristics of iron ore slurry at different solid concentrations revealed a significant dependence on solids loading. Experimental observations showed that the settling rate increased with decreasing solid concentration. At 20% solids concentration, the slurry exhibited slow settling behaviour due to increased particle interaction and hindered settling effects. As the concentration decreased from 20% to 5%, the settling velocity increased considerably because of reduced viscosity and lower resistance to particle movement. The 5% slurry concentration exhibited the fastest settling rate and attained a nearly constant interface height within a shorter duration. This behaviour confirms that lower slurry concentrations favour discrete settling conditions and reduce interparticle interference



Table 1. Weight of Slurry at Different Solid Concentrations

Solid Concentration (%)	Weight (g)
20	279.23
15	269.41
10	259.79
5	248.44

Figure 1. Slurry weighing and sample preparation process

The effect of acidic and alkaline conditions on settling behaviour was investigated using HCl and NaOH. The addition of HCl reduced the pH of the slurry and resulted in improved settling performance. Under acidic conditions, electrostatic repulsion between particles decreased, promoting particle agglomeration and faster sedimentation. In contrast, NaOH addition increased slurry alkalinity and produced comparatively slower settling behaviour. The alkaline environment increased particle dispersion and reduced the tendency of fine particles to aggregate effectively.

The experimental results indicate that acidic conditions favour improved settling efficiency compared to alkaline conditions for the studied iron ore slurry.



Figure 2. Weight measurement setup and dried slurry sample. **Figure 3.** Settling behaviour of slurry at different solid concentrations.

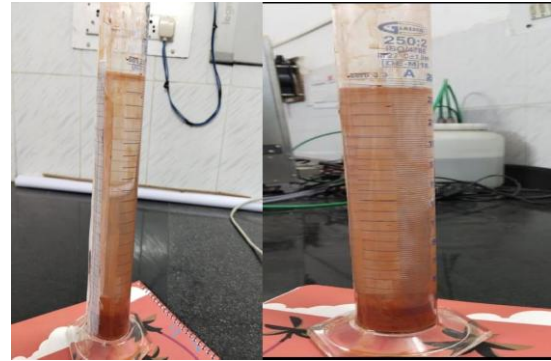


Table 2. Settling Data at Different Solid Concentrations

Time (min)	20% Solid	15% Solid	10% Solid	5% Solid
3	0.3	0.5	0.8	5.3
15	0.6	1.6	5.1	20.4
30	2.6	3.1	10	21.6
60	6.6	9.4	15.6	21.7
120	9	11.6	15.8	21.7
180	9.7	12.1	15.8	21.7

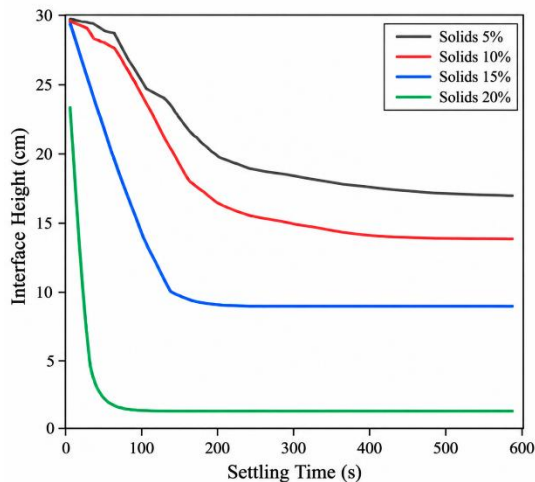


Fig. 4. Variation of interface height with settling time at different solids concentration.

Table 3. Settling Behaviour after Acid and Base Addition

Time (min)	20% HCl	20% NaOH
3	0.4	0.3
15	3.3	1.2
30	7.7	2.1
60	9.5	3.9

4.1 Effect of pH variation and Lime addition

Lime addition significantly improved the settling characteristics of the slurry. Lime acts as a pH-modifying and coagulating agent that enhances particle aggregation through charge neutralization and formation of hydroxide complexes.

The settling curve obtained after lime addition showed a steady increase in interface movement with time, indicating enhanced sedimentation performance. The increase in alkalinity promoted

stronger interparticle attraction and facilitated the formation of larger aggregates. The results suggest that lime can be effectively used as a low-cost additive for improving dewatering and thickening operations in iron ore processing industries.



Fig. 5. Acid–base mixing setup and pH measurement arrangement.



Fig. 6. Lime addition to slurry sample before settling analysis

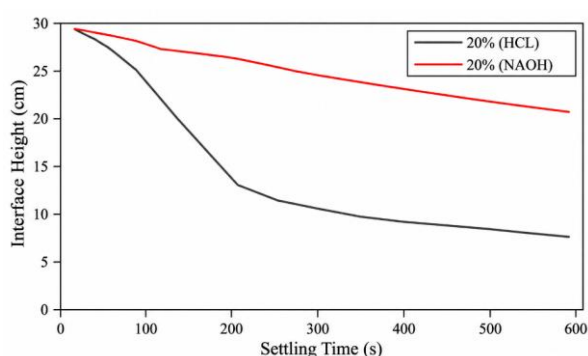


Fig. 7. Effect of acidic and alkaline medium on settling characteristics.

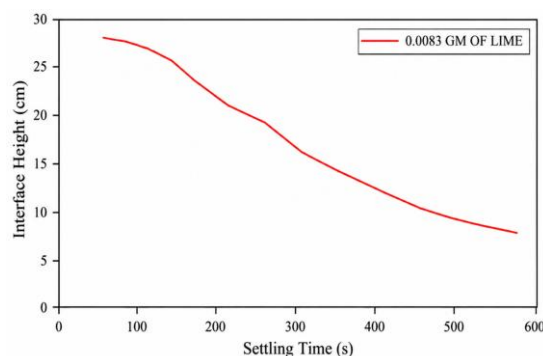


Fig. 8. Settling profile of slurry after lime addition.

Table 4. Settling Behaviour after Lime Addition

Time (min)	Interface Height
3	0.4
15	1.5
30	3.5
60	7

Table 5. Effect of Flocculant Dosage on Settling Behaviour

Time (min)	30 g/t	50 g/t	70 g/t
3	0.4	0.6	1.4
15	4.3	5.5	6.9
30	8.6	9.2	9.7
60	10.7	11	11.3

4.2 Effect of Flocculant Dosage

The most significant improvement in settling performance was observed with the addition of polyacrylamide flocculant. Flocculant addition promoted rapid aggregation of fine particles through polymer bridging mechanisms.

Among the investigated dosages, the highest flocculant concentration produced the fastest settling rate and clearest supernatant liquid. Larger and denser flocs formed during flocculation settled rapidly, thereby improving solid–liquid separation efficiency. The settling curves demonstrated that increasing flocculant dosage substantially enhances sedimentation kinetics and reduces settling time. However, optimum dosage selection is important for achieving maximum efficiency and economic feasibility.



Fig. 9. Flocculant mixing and settling observation setup.

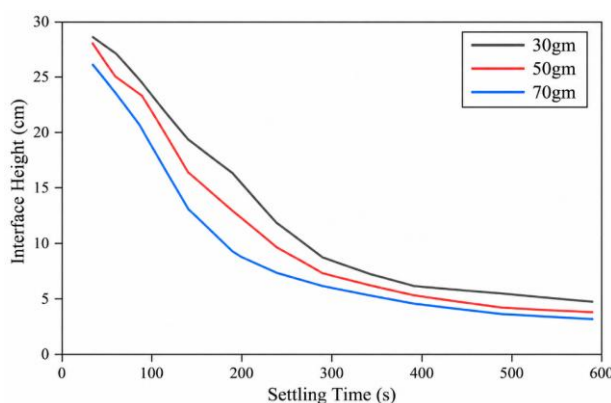


Fig. 10. Effect of flocculant dosage on settling characteristics of iron ore slurry.

5. Conclusion

The present investigation successfully evaluated the settling behaviour of iron ore slurry under different operational conditions including variation in solids concentration, pH adjustment, lime addition, and flocculant dosage. The experimental results demonstrated that settling velocity increases with decreasing solids concentration due to reduced hindered settling effects. Acidic conditions enhanced sedimentation by promoting particle agglomeration, whereas alkaline conditions produced relatively slower settling. Lime addition improved settling efficiency by modifying slurry alkalinity and facilitating interparticle attraction. Among all the investigated methods, polyacrylamide flocculant produced the most significant enhancement in settling rate owing to rapid floc formation and improved sedimentation kinetics. The study confirms that proper control of physicochemical parameters can substantially improve solid–liquid separation efficiency in iron ore tailings management. The generated data can be effectively utilized for thickener design, process optimization, and sustainable dewatering

operations in mineral processing industries. Although significant research has been conducted on iron ore slurry settling and flocculation, several important gaps remain in understanding the combined influence of process variables under industrial conditions. These developments can contribute significantly toward sustainable tailings management and improved water recovery in mineral processing industries.

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