

# Maximising RIMM Water Savings for Complex Clay Ore Processing.

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The Resin-in-Moist-Mix (RIMM) process has emerged as a promising approach for the selective recovery of valuable metals from complex ores and waste materials through simultaneous leaching and resin-based sorption in a moisturised mix state. Contrary to conventional slurry processing, the process operates under controlled moisture conditions, creating an opportunity for significant water savings. However, efficient water management remains a critical challenge when processing clay-rich ores, where high water retention, slow settling, and poor consolidation behaviour are commonly observed. This study establishes baseline dewatering behaviour for representative RIMM tailings derived from saprolite, siliceous goethite and goethitic ores prior to reagent optimisation to increase dewatering efficiency. Mineralogical analysis indicates significant variation in clay and silicate mineral content among the ores, with saprolite containing substantial Mg-bearing silicates and smectite phases, while siliceous goethite is dominated by quartz and goethite, and the goethitic ore is enriched in iron oxyhydroxides. Baseline settling, turbidity, rheology and cake moisture measurements are used to characterise natural sedimentation behaviour under controlled conditions to provide understanding of the interplay between mineral pulp chemistry, particle interactions, and dewatering performance of fine dispersions.

Keywords: RIMM tailings, dewatering, water recovery, solid–liquid separation, clay minerals.

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## 1. Introduction

Tailings are the residual waste materials produced during the extraction of valuable mineral commodities from ore in mineral processing operations (Chryss, 2017). They typically consist of finely ground rock particles, clay minerals, and residual dissolved metals dispersed in process water containing various chemical reagents used during ore beneficiation (Chryss, 2017). The downstream handling, treatment and disposal of tailings are critical components of mineral processing operations because they require the effective separation of solid residues from process liquids to enable the recovery and recycling of water back into the processing circuit (Joseph-Soly et al., 2021; Joseph-Soly et al., 2020). Efficient water recovery is increasingly important as mining operations face growing environmental and operational pressures related to water consumption, tailings storage capacity and sustainable resource management (Burritt & Christ, 2018; Segura et al., 2016). Techniques available for solid-liquid separation, include filtration, centrifugation and gravity thickening. Among these, gravity thickening is often the most practical and widely applied method in mineral processing operations because it allows large volumes of slurry to be treated with relatively low energy

consumption while achieving acceptable clarification and sediment consolidation performance (Witham et al., 2012). The design and optimisation of dewatering systems require the integration of several criteria, including particle size distribution, mineral composition, suspension stability and the behaviour of fine slimes present in the tailings (Dash et al., 2011). In particular, the generation and behaviour of fine particles suspensions play a critical role in determining the efficiency of solid–liquid separation processes (Dash et al., 2011). As ore is ground to finer sizes, the proportion of particles with low settling rates increase (Bahmani-Ghaedi et al., 2022). The stability of such suspensions can be influenced by several physicochemical parameters including pH, ionic strength, surface charge and the presence of dissolved ions in the process water (Dash et al., 2011). Coagulants or polymeric flocculants are therefore commonly employed to destabilise suspensions by promoting particle aggregation, which increases particle size and enhances gravity-driven sedimentation (Orchard et al., 2024; Teh et al., 2016).

The challenge of suspension stability is exacerbated in systems containing large proportions of clay minerals. Clay minerals significantly influence the handling and storage of tailings, particularly during thickening, transport, settling, dewatering and water recovery processes. Their presence affects aggregate density, making it difficult to achieve high solids concentrations in thickened tailings. Swelling clays, such as smectites, can alter the flow behaviour of suspensions, reducing settling rates, promoting particle segregation and increasing energy requirements during pumping. In addition, the high surface area of clay particles can increase reagent consumption and reduce the clarity of water recovered for reuse in the process (Addai-Mensah, 2007; Chryss, 2017). These issues are relevant when processing lateritic ores. Lateritic ores are characterised by complex mineralogical compositions that include iron oxyhydroxides such as goethite and hematite, aluminosilicate clays such as kaolinite and smectite, and various silicate minerals including quartz and magnesium-bearing silicates (Dalvi et al., 2004; Zappala et al., 2024). Mineralogical differences can significantly influence the rheological and sedimentation behaviour of suspensions (Liu et al., 2018; Luo et al., 2024). Lateritic ores are characterised by a wide particle size distribution with fractions of fine and ultrafine particles (<50 µm) which impacts their processing behaviour (Fan & Gerson, 2013; Zappala et al., 2024). Upstream processes such as mechanical activation can alter ore properties by reducing particle size, increasing surface area, and modifying structure of nickel laterites to enhance Ni and Co recovery (Gertrude et al., 2026), which may affect downstream dewatering behaviour of lateritic tailings. Quast et al. (2015), demonstrated that the natural settling behaviour of nickel laterite slurries is strongly influenced by particle surface charge: at the natural pH goethitic laterites were uncharged resulting in minimal repulsion between particles and settled rapidly. In contrast, siliceous goethitic and saprolitic laterites have strong negative zeta potentials (−28 mV and −40 mV, respectively and settle more slowly. They also showed that under high saline conditions (2 M NaCl), primary dewatering of fine stirred mill products (<38 µm) could achieve sediment solids >20 wt.%, and that the use of selected flocculants (Rheomax 1010 and BASF 342) significantly increased settling rates and improved supernatant clarity, although substantial flocculant dosages were required. Recent studies by Keskin and Can (2024), investigated the settling behaviour of nickel laterite residues post HPAL using different flocculant types. They reported that non-ionic flocculants performed

better and gave the most stable results, anionic flocculants showed positive results however effective flocculation decreased with increasing molecular weight and anionicity grade. On the other hand, cationic flocculants provided fast settling and good clarity values but were not preferred in ores that have low solid content. It is also important to note that the complex mineralogy in laterite ores makes process controllability difficult leading to instantaneous changes in the system continuously which causes variability to settling behaviour (Keskin & Can, 2024).

The Resin in Moist Mix (RIMM) process, a patented technology jointly developed and owned by InnovEco and Oryxeio is a selective metal recovery technique that can be integrated into processing flowsheets, offering high metal recovery with reduced consumption of leaching agents and lower residual metal and reagent levels in process residues (Spiridonov et al., 2016). The process has been evaluated for a range of materials, including low-grade ores and tailings containing metals such as copper, cobalt, and nickel (Spiridonov et al., 2016). In contrast to conventional hydrometallurgical systems that rely on dilute slurry (pulp) leaching, the RIMM process operates by facilitating direct contact between ion exchange resins and wet solids, RIMM enables selective leaching and sorption of target metals being conducted in the state of a moisturised mix (Spiridonov et al., 2016; Spiridonov et al., 2019). Despite its reduced water requirement during leaching, the downstream separation of resins from the treated solids, requires additional water input for effective washing and recovery. Clay-rich systems further complicate this, as fine particles promote suspension stability, hinder solid–liquid separation and increase water retention within the matrix. As a result, the overall water saving advantage of the process may be reduced. The integration of an effective dewatering strategy within the RIMM processing framework is essential to maximise water recovery and maintain optimal moisture conditions for the process. Understanding the baseline sedimentation and water retention behaviour of RIMM tailings is therefore a critical first step toward designing appropriate dewatering strategies. Establishing these baseline characteristics provides insight into how mineralogical composition influences suspension stability, settling kinetics and sediment moisture content. Such understanding will guide the selection and optimisation of chemical conditioning strategies, including flocculants and coagulants, to improve particle aggregation and maximise water recovery from RIMM process.

In this study, dewatering behaviour is investigated for representative RIMM tailings derived from saprolite, siliceous goethite and goethite ores without flocculant addition. Investigations were carried out on the three tailing types of different mineralogy in terms of surface charge, settling, supernatant clarity, rheology, and moisture content. Mineralogical analysis reveals variation between these materials, with saprolite containing significant quantities of magnesium-bearing silicates and smectite group minerals, siliceous goethite dominated by quartz and goethite phases, and the goethite ore enriched in iron oxyhydroxides. The findings of this work aim to provide insights into influence of mineralogy on particle interactions and settling behaviour and guide future reagent-assisted dewatering investigations aimed at maximising water recovery in RIMM process.

## 2. Experimental

### 2.1 Materials

RIMM tailings used in this study were obtained from laboratory-scale RIMM processing of a silicious goethite (SG), limonite (G) and saprolite (SAP) ores. These ores represent mineralogically distinct lateritic materials with clay fractions. The major minerals present in the three samples comprised quartz, Mg-bearing silicates, smectite group, and goethite. Minor phases such as chromite, maghemite, hematite, kaolinite and other trace minerals were also identified across the three samples. Details of the mineralogical analyses established by Quantitative Evaluation of Minerals by Scanning Electron Microscopy (QEMSCAN) is presented in Table 1.

The particle size distributions (PSD) of the samples were determined by laser diffraction (Malvern Mastersizer X, Malvern, UK). The size classification of the RIMM tailings as presented in Fig. 1 shows 10% of particles of SG and G samples are of colloidal size (0.1–5  $\mu\text{m}$ ), which may cause colloidal stability issues with respect to supernatant turbidity. The  $d_{90}$ ,  $d_{50}$  and  $d_{10}$  particle sizes were 39, 15, 3  $\mu\text{m}$ , respectively for SG, 52, 9 and 3  $\mu\text{m}$  respectively for G and 156, 39, and 6  $\mu\text{m}$  respectively for SAP.

Demineralised water was used for all slurries and solutions preparation. All slurries were prepared using  $10^{-3}$  M  $\text{KNO}_3$  solution and tests were conducted at pH 3, 5, 7 and 9 respectively.

Table 1

Mineralogical composition of lateritic feed samples as revealed by QEMSCAN analysis.

Mineral	SG (wt.%)	G (wt.%)	SAP (wt.%)
Chromite	3.09	2.95	3.81
Maghemite	0.51	1.04	0.41
Goethite	26.64	60.43	20.40
Hematite	0.53	15.70	7.14
Magnetite	-	3.95	-
Gibbsite	-	1.22	0.03
Mn Oxides	0.01	0.95	0.02
Kaolinite	0.62	3.61	0.3
Mg-bearing silicates	7.78	1.49	28.77
Quartz	39.41	2.14	5.25
Smectite group	13.42	0.28	20.70
Alunite	-	0.17	-
Galaxite	0.05	0.02	0.07
Others	8.31	6.06	13.10

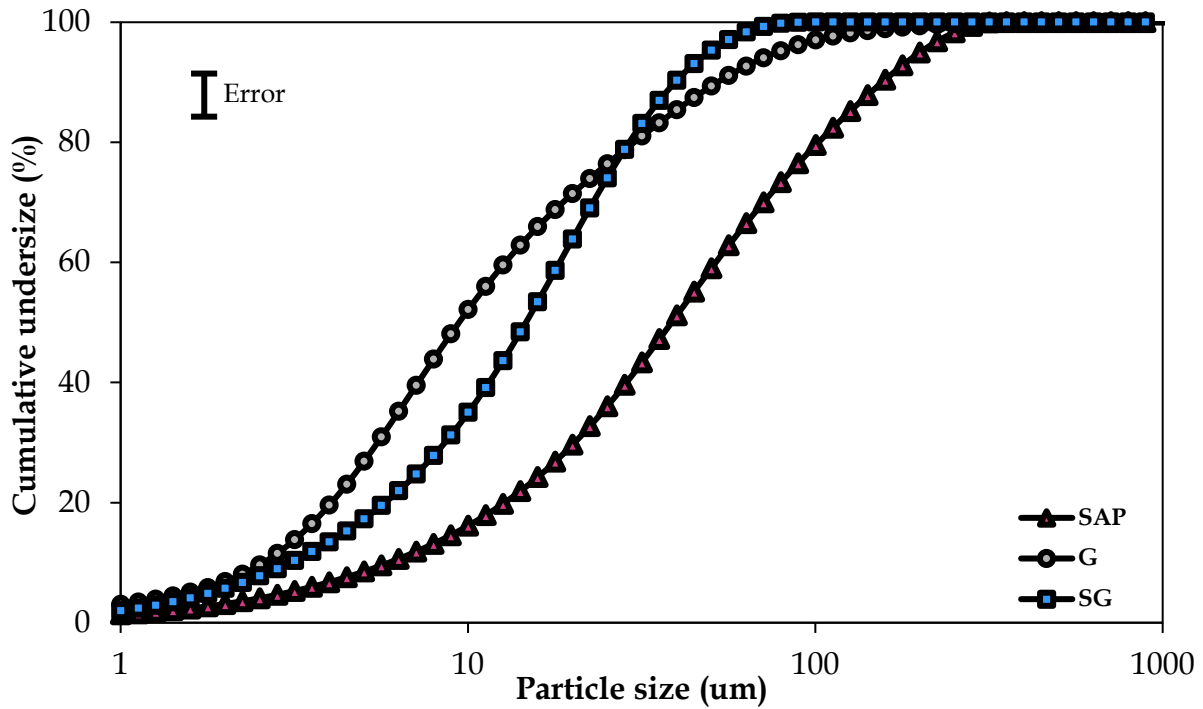


Fig. 1 Particle size distribution of SAP, G and SG.

## 2.2 Methods

### 2.2.1 Zeta Potential Measurements

Zeta potential ( $\zeta$ ) measurements of the RIMM tailings were carried out to evaluate the surface charge characteristics of the particles as a function of pH with a Nano-ZS Zetasizer apparatus (Malvern instruments, Malven, U.K). Measurements were conducted on agitated aqueous suspensions prepared with the particles dispersed in a  $10^{-3}$  M  $\text{KNO}_3$  background electrolyte solution to minimise the influence of anomalous surface conductance on the measured zeta potential. The suspensions were conditioned at different pH values using analytical grade KOH and  $\text{HNO}_3$  solutions, and measurements were performed using electrophoretic light scattering mode. Prior to analysis, the instrument was calibrated using standard buffer solutions. Agitation was maintained at controlled stirring rate to ensure homogeneous dispersion during measurements.

### 2.2.2 Sedimentation Studies

Slurry settling experiments were carried out using tailings suspensions prepared at 6 wt.% in  $500 \text{ cm}^3$  graduated cylinders at varying pH conditions. To perform settling test, solid samples were added to the electrolyte background and mixed after sealing the cylinder and turning it upside down 10 times to ensure slurry was uniformly mixed. The initial settling rate of the flocculated suspension was determined by recording the time taken for the “mud line” (solid-liquid interface) in the cylinder to cover a distance of  $\sim 8.1 \text{ cm}$  below the  $310 \text{ cm}^3$  mark (Addai-Mensah, 2007).

### 3. Results and discussion

#### 3.1 Zeta potential measurements

The zeta potential study using a dilute slurry in distilled  $10^{-3}$  M  $\text{KNO}_3$  electrolyte background as a function of pH is shown in Fig. 2. It can be seen from this figure that the particle surfaces of SG and SAP carry a net negative charge under the tested pH conditions, with zeta potential becoming more negative as the pH increases, and no isoelectric point (IEP) observed. The decrease in negativity of zeta potential with increase in pH could be explained by the adsorption of  $\text{OH}^-$  onto the mineral surface (quartz) leading to a large diffuse electrical double layer (Kaya & Yukselen, 2005; Quast et al., 2015). The zeta potential for G follows a similar trend; however, it exhibits positive surface charge at low pH and an isoelectric point at approximately pH 5.7, indicating the dominance of iron oxyhydroxide phases such as goethite, which are known to undergo surface charge reversal with increasing pH (Madigan et al., 2009; Quast et al., 2015).

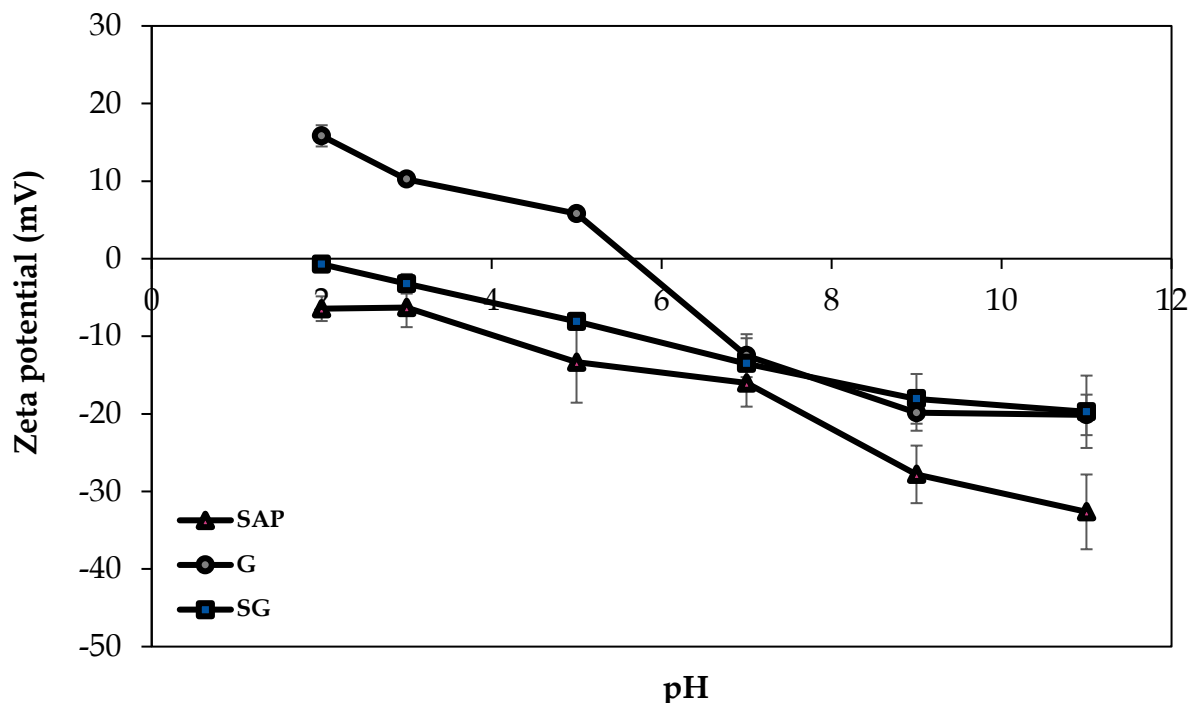


Fig. 2 Particle zeta potentials of SAP, G and G slurries in  $10^{-3}$  M  $\text{KNO}_3$ .

#### 3.2 Dewatering behaviour of dilute slurries

The gravity settling behaviour of 6 wt.% lateritic tailings suspensions (SG, SAP, and G) was evaluated under varying pH conditions. The settling behaviour was characterised by relatively low settling rates across all ore types, indicating a degree of suspension stability in the absence of flocculants. Initial settling rates ranged from approximately 1.20 to 1.98 m/h at pH 3, with SG exhibiting the highest settling rate ( $\sim 1.98$  m/h), followed by SAP ( $\sim 1.95$  m/h), and G showing the slowest settling behaviour ( $\sim 1.20$  m/h).

For all ore types, settling rates decreased with increasing pH, suggesting enhanced particle dispersion and reduced aggregation under more alkaline conditions. The decrease in settling rate with increasing pH is attributed to increased negative surface charge on mineral particles, which enhances electrostatic repulsion and stabilises the suspension. Similar behaviour has been reported for nickel laterite slurries, where settling is influenced by zeta potential and particle–particle interactions (Quast et al., 2015). The relatively low settling rates indicate that conventional gravity settling without flocculant addition is inefficient for these systems. The results suggest that extended residence times would be required to achieve acceptable solid-liquid separation.

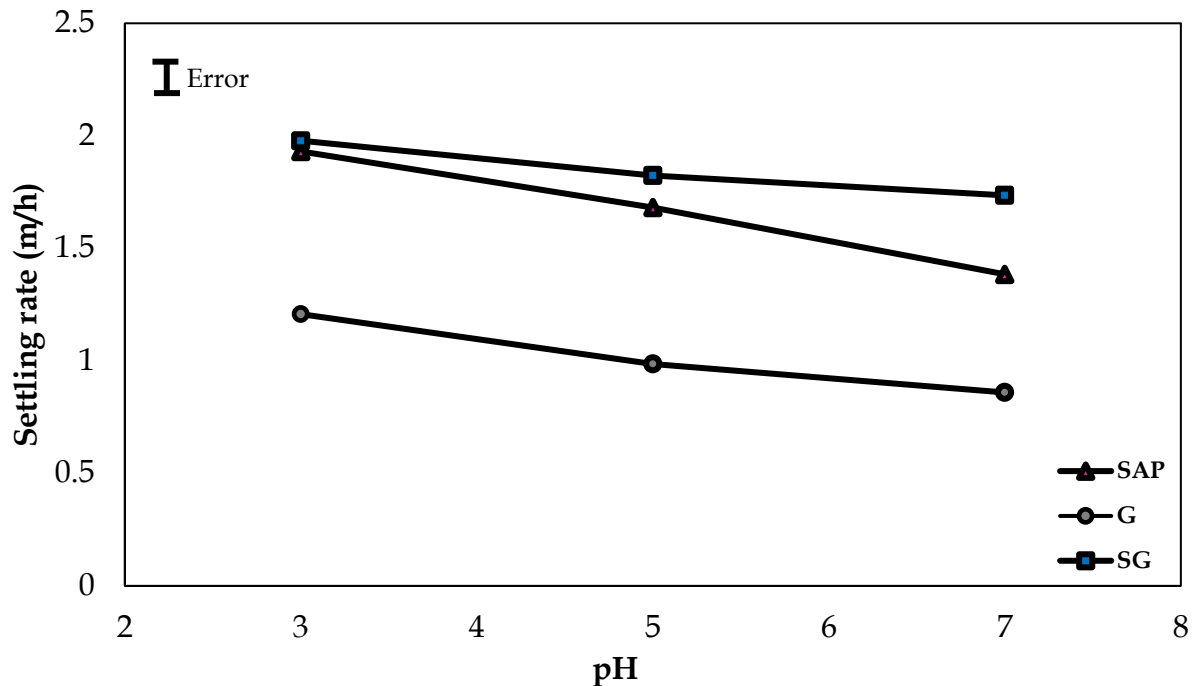


Fig. 3 Initial settling rate of 6 wt.% solid slurries at pH 3, 5 and 7.

#### 4. Conclusions and future work

Tests performed in terms of size classification, surface zeta potential and settling behaviour of dilute slurries without flocculant addition were conducted to characterise the dewatering behaviour of RIMM tailings derived from saprolite, siliceous goethite and goethitic ores. Particle size distribution analysis showed that the RIMM tailings consist predominantly of fine particles, with approximately 10% of the siliceous goethite and goethite samples falling within the colloidal size range (0.1–5  $\mu\text{m}$ ). Zeta potential measurements showed that the siliceous goethite (SG) and saprolite (SAP) tailings exhibited consistently negative surface charges across the investigated pH range, becoming increasingly negative with increasing pH. In contrast, the goethitic (G) tailings displayed positive surface charge under acidic conditions and reached an isoelectric point at approximately pH 5.7, after which the surface charge became negative. Settling experiments showed generally poor sedimentation behaviour across all slurry types and tested pH conditions. The dilute suspensions exhibited relatively low settling rates, indicating stable dispersions in the absence of flocculants.

Future studies will include the evaluation of supernatant clarity using turbidity measurements to quantify suspension stability and fine particle dispersion. Rheological investigations of the slurries will also be conducted to characterise particle–particle interactions that influence pulp flow, and handleability. In addition, measurements of the moisture content of the consolidated sediment cake will be performed to assess water retention within the tailings. These investigations will help guide reagent selection and know the opposite effects of reagent assisted dewatering to understand interaction between flocculants and particle surfaces to obtain the best result for improved dewatering characteristics.

## REFERENCES

- Addai-Mensah, J. (2007). Enhanced flocculation and dewatering of clay mineral dispersions. *Powder Technology*, 179(1-2), 73-78.
- Bahmani-Ghaedi, A., Hassanzadeh, A., Sam, A., & Entezari-Zarandi, A. (2022). The effect of residual flocculants in the circulating water on dewatering of Gol-e-Gohar iron ore. *Minerals Engineering*, 179, 107440.
- Burritt, R. L., & Christ, K. L. (2018). Water risk in mining: Analysis of the Samarco dam failure. *Journal of cleaner production*, 178, 196-205.
- Chrissy, A. (2017). *Effects of Clay in Tailings Handling and Storage*. Cambridge University Press, Cambridge.
- Dalvi, A. D., Bacon, W. G., & Osborne, R. C. (2004). The past and the future of nickel laterites. PDAC 2004 International Convention, Trade Show & Investors Exchange,
- Dash, M., Dwari, R., Biswal, S., Reddy, P., Chattopadhyay, P., & Mishra, B. (2011). Studies on the effect of flocculant adsorption on the dewatering of iron ore tailings. *Chemical Engineering Journal*, 173(2), 318-325.
- Fan, R., & Gerson, A. R. (2013). Mineralogical characterisation of Indonesian laterites prior to and post atmospheric leaching. *Hydrometallurgy*, 134, 102-109.
- Gertrude, A., Skinner, W., Abaka-Wood, G., Pavel, S., Jonas, A.-M., & Richmond, A. (2026). Extraction of Nickel and Cobalt from Complex Low-Grade Lateritic Ores: Challenges and Opportunities. *Minerals*, 16(3), 287.
- Joseph-Soly, S., Asamoah, R., & Addai-Mensah, J. (2021). Superabsorbent recycling for process water recovery. *Chemical Engineering Journal Advances*, 6, 100085.
- Joseph-Soly, S., Asamoah, R. K., Skinner, W., & Addai-Mensah, J. (2020). Superabsorbent dewatering of refractory gold concentrate slurries. *Advanced Powder Technology*, 31(8), 3168-3176.
- Kaya, A., & Yukselen, Y. (2005). Zeta potential of clay minerals and quartz contaminated by heavy metals. *Canadian Geotechnical Journal*, 42(5), 1280-1289. <https://doi.org/10.1139/t05-048>
- Keskin, Ö., & Can, M. (2024). Investigation of the settling behavior of lateritic nickel ores in the CCD process after HPAL. *Dicle Üniversitesi Mühendislik Fakültesi Mühendislik Dergisi*, 15(1), 191-200.
- Liu, D., Edraki, M., & Berry, L. (2018). Investigating the settling behaviour of saline tailing suspensions using kaolinite, bentonite, and illite clay minerals. *Powder Technology*, 326, 228-236.
- Luo, Y., Ekanayake, N. I., Amini, N., Moon, E., Hapgood, K., Scales, P. J., & Stickland, A. D. (2024). Quantifying the effects of clays on mineral tailings filtration. *Minerals Engineering*, 216, 108830.
- Madigan, C., Leong, Y.-K., & Ong, B. (2009). Surface and rheological properties of as-received colloidal goethite ( $\alpha$ -FeOOH) suspensions: pH and polyethylenimine effects. *International Journal of Mineral Processing*, 93(1), 41-47.
- Orchard, M. J., Yang, G., Webber, G. B., Franks, G. V., & Zhao, C.-X. (2024). Development of bioflocculants for mineral processing. *Materials Today Sustainability*, 28, 100965.
- Quast, K., Connor, J. N., Skinner, W., Robinson, D. J., & Addai-Mensah, J. (2015). Preconcentration strategies in the processing of nickel laterite ores Part 4: Preliminary dewatering studies. *Minerals Engineering*, 79, 287-294.
- Segura, F. R., Nunes, E. A., Paniz, F. P., Paulelli, A. C. C., Rodrigues, G. B., Braga, G. Ú. L., dos Reis Pedreira Filho, W., Barbosa Jr, F., Cerchiaro, G., & Silva, F. F. (2016). Potential risks of the residue from Samarco's mine dam burst (Bento Rodrigues, Brazil). *Environmental Pollution*, 218, 813-825.

- Spiridonov, P., Hein, H., & Asamoah, R. (2016). The RIMM process—an advanced metal extraction method. ALTA annual conference proceedings nickel/cobalt conference, Perth,
- Spiridonov, P., Skinner, W., Addai-Mensah, J., Hein, H., & Asamoah, R. (2019). Investigation of the resin in moist mix process for the nickel and cobalt recovery from laterites. ALTA 24th annual conference proceedings nickel-cobalt-copper conference, Perth,
- Teh, C. Y., Budiman, P. M., Shak, K. P. Y., & Wu, T. Y. (2016). Recent advancement of coagulation–flocculation and its application in wastewater treatment. *Industrial & Engineering Chemistry Research*, 55(16), 4363-4389.
- Witham, M., Grabsch, A., Owen, A., & Fawell, P. (2012). The effect of cations on the activity of anionic polyacrylamide flocculant solutions. *International Journal of Mineral Processing*, 114, 51-62.
- Zappala, L., McDonald, R., & Pownceby, M. I. (2024). Nickel laterite beneficiation and potential for upgrading using high temperature methods: A review. *Mineral Processing and Extractive Metallurgy Review*, 45(7), 767-789.