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Dewatering capabilities of Terraflowing™ technology for tailings

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Abstract

Tailings dewatering through high-pressure cycloning produces high-density tailings which, depending on the particle size distribution (PSD), can be used as a coarse sand resource or deposited as high solids concentration tailings. The Terraflowing™ dewatering process includes one or more high-pressure cycloning steps to produce a highly dewatered product. The process has been tested in the Weir Technical Centre (WTC) on more than eight different tailings samples, representing five commodities. Copper and gold tailings make up the majority of the tested samples, but iron ore, nickel and coal tailings have also been tested. These tests have proven to deliver comparable positive results for different samples. Adjusting the operational conditions, specifically the feed pressure of the cyclone, is known from previous work to accommodate variations in PSD. The compared results for the individual samples have been produced with optimal equipment settings for the tested sample.

Comparing the results of the tested samples indicates that a steady recovery of solids and steady underflow density is achieved in the primary cycloning step. For most of the considered samples, this step produces a self-draining product with 70 to 80% solids concentration by weight. The solids concentration of the final blended product is controlled by the level of dewatering achieved in the final centrifugation step. The maximum dryness of the pulp depends on the (ultra) fines fraction. A finer tailings achieves a lower pulp moisture level; hence the blended solids concentration is affected. The presence of a significant percentage of fines has a positive effect on the ability to produce paste.

This paper explores the versatility of the process and its capability to generate high-density products across various commodities with different tailings characteristics. The impact of variations in PSD and feed solids concentration on dewatering performance is illustrated through the testwork results.

Keywords: *tailings, tailings dewatering, terraflowing, hydrocyclone, hydrocyclone, decanter centrifuge, performance comparison, copper tailings, iron ore tailings, nickel tailings, gold tailings, zinc tailings, coal tailings, repurposing, paste tailings, high-density tailings, tailings management, water preservation*

1 Introduction

Mining plays a crucial role in the supply of the resources required for the energy transition. The increased demand for low-grade ores results in a rapid growth in the volume of tailings to be dealt with. Traditional tailings disposal methods may have been cost effective; however, they pose a significant risk when dam construction, disposal and closure are not well managed. There is a trend towards dryer tailings; while this is primarily driven by stability improvements, it also enhances water stewardship.

Recovering part of the tailings stream for use as construction material converts a waste stream to a value stream. Most tailings allow for the recovery of a valuable fraction, which can be utilised either in dam construction or to enhance permeability in the tailings storage facility (TSF).

Regardless of the intended use, maintaining consistent product properties is important. Traditional dewatering circuits are susceptible to variation in both feed and process conditions. Consequently, the TSF design must account for potential fluctuations in product properties. The Terraflowing™ dewatering process developed by Weir Minerals provides a versatile dewatering solution for tailings.

This paper focuses on the testwork results achieved for eight different samples representing five commodities: copper, gold, nickel, iron ore and coal.

The recovery of a construction grade value stream from the PSD is possible, as demonstrated by Steward et al. (2020) The main objective of this paper is to compare the process performance. More information on the recovery of a self-draining classified tailings stream for dam construction using the Terraflowing process can be found in the work done by Steward et al. (2020).

2 Terraflowing dewatering process flow concept

The Terraflowing tailings dewatering process was developed at the Weir Technical Centre (WTC) in response to increased stakeholder pressure to produce tailings that are both reduced in quantity and notably drier. The concept has been developed with the objective of providing:

- Versatility in the delivered product(s). The process facilitates the recovery of a valuable product from the tailings stream and/or disposal of the dewatered full plant tailings.
- Consistent properties of the dewatered product(s). Improved process control reduces the variation in product properties, combined with the ability to change product properties when required.
- Ease of operational control. Combining dewatering technologies with the ability of real-time operational control enables efficient process control, ensuring that product properties consistently adhere to specified requirements.

Fundamentally, the concept intends to ‘engineer’ a high-density, paste-like tailings product suitable for deposition, whilst enabling the recovery of a construction grade product whenever necessary or feasible.

The process incorporates a two-stage cyclone dewatering process followed by centrifugation of the final stage of cyclone overflow. In this process, three dewatered tailings streams are produced: a primary cyclone underflow, a secondary cyclone underflow and a centrifuge pulp. These three streams can be combined or used in different configurations. By varying the cyclone and centrifuge configurations and operation in this three-stage system, the Terraflowing process can deal with feed variations in particle size distribution (PSD) and mineralogy while delivering variations in PSD, tailings solids concentrations and recoveries. The flexibility provided by this approach enables optimisation of power utilisation by adjusting the degree of dewatering in accordance with local conditions. The process is structured around the process flow diagram shown in Figure 1:

- Primary cycloning to achieve the highest possible cyclone underflow solids concentration and recovery of solids.
- Secondary cycloning of the primary cyclone overflow (pCOF) to achieve the highest possible cyclone underflow solids concentration and solids recovery.
- Centrifuging of the secondary cyclone overflow (sCOF) to recover the remaining tailings at the maximum achievable solids concentration together with the recovery of a final water that is suitable for return to the process plant.
- Mixing of the two cyclone underflows and centrifuge pulp to produce a continuous dewatered tailings stream.
- Pumping the dewatered tailings to the place of deposition.

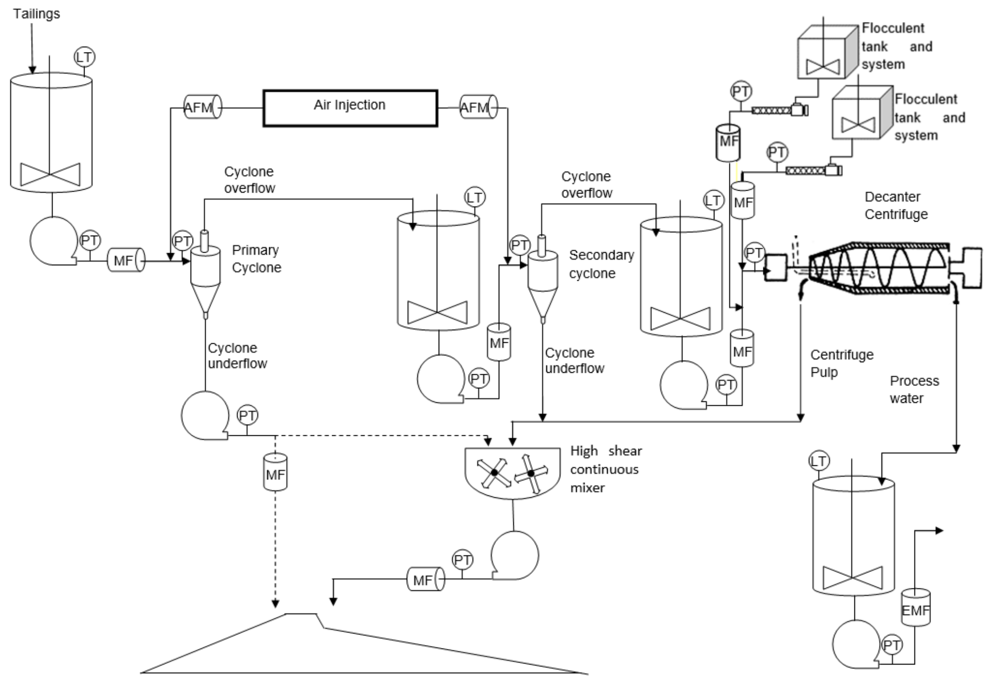


Figure 1 The Terraflowing dewatering process

3 Test methodology

Tailings samples of eight different mining operations have been evaluated. The samples span five commodities: three copper tailings samples, two iron ore tailings samples, and single samples of gold, nickel and coal (Table 1).

The individual samples have been part of the Terraflowing Development Program, which is described in more detail by Steward et al. (2020). In this paper, the results of the test campaigns for the eight samples are compared. The Terraflowing test program methodology can be summarised in the following steps:

- The feed test material was characterised with respect to PSD and specific gravity (SG).
- The primary and secondary stage cyclones were optimised for cyclone underflow PSD, solids concentration and recovery by adjusting some or all of the following depending on the required outcome:
  - Cyclone configuration.
  - Spigot and vortex finder diameter and length.
  - Tailings feed pressure and solids concentration.
  - Cyclone air injection pressure and volume.
- Centrifugation optimisation was conducted to maximise the solids concentration of the centrifuge pulp, while minimising the solids concentration in the centrate.

Table 1 List of samples and tested process

Sample	Commodity	Circuit
Tailings 1	Copper	Primary cyclone + secondary cyclone + centrifuge
Tailings 2	Copper	Primary cyclone + secondary cyclone + centrifuge
Tailings 3	Copper	Primary cyclone + secondary cyclone + centrifuge
Tailings 4	Coal	Primary cyclone + secondary cyclone + centrifuge
Tailings 5	Nickel	Primary cyclone + secondary cyclone + centrifuge
Tailings 6	Iron	Primary cyclone + secondary cyclone + thickener
Tailings 7	Iron	Primary cyclone + secondary cyclone + centrifuge
Tailings 8	Gold	Primary cyclone

Two exceptions to the standard test sequence have been included in the comparison. In the test campaign of Tailings 6, the secondary cyclone overflow has been thickened rather than centrifuged as the customer already had the thickeners installed.

The testwork campaign for Tailings 8 deviated from this approach as the sample was part of a test campaign to demonstrate the ability to produce a construction grade, self-draining underflow product for dam construction. The sample has been solely primary cycloned.

3.1 Cycloning

For the execution of the cycloning testwork, a special cyclone test rig was used. The rig allows for the measurement of solids mass and flow split. The bulk sample is run through the selected Cavex® hydrocyclone in a closed loop. When stable operating conditions are reached, the cyclone overflow and cyclone underflow are collected in separate (split) samples.

The collected primary cyclone overflow is then cycloned again, using the optimal hydrocyclone configuration. The dedicated WTC cyclone test rig is presented in Figure 2a.

(a) (b)

Figure 2 Test setup: (a) Cyclone test rig; (b) Centrifuge and thickener test rigs

3.2 Centrifugation

The secondary cyclone overflow is dewatered using a decanter centrifuge. The use of flocculant is required to achieve high solids recovery and clear centrate (Steward et al. 2020). The centrifuge test rig is depicted in Figure 2b.

The final product is produced by mixing the primary cyclone underflow, the secondary cyclone underflow and the pulp in a paddle mixer.

For every cyclone or centrifuge test, the PSD was measured by laser diffraction techniques and the solids concentration was measured by oven drying at 95°C. The solids flow rate (t/h) of the respective streams was calculated and, thus, the mass split or recovery to the different streams could be determined as a percentage of the feed solids flow rate (t/h) (Steward et al. 2020).

4 Tailings properties

Material properties of the tested samples may impact the results that can be achieved. The material properties of the eight tested tailings are listed in Table 2. The three copper tailings samples tested have an identical solids SG of 2.7 but vary in solids concentration of the full plant tailing stream. The iron ore tailings samples considered show an inverted trend; they have similar dilute tailings streams, but the solids SG of the Tailings 7 sample is 10% higher compared to the Tailings 6 sample.

Table 2 Tailings samples solids concentration, solids SG and commodity

Sample	Commodity	Feed C_w	Solids SG
Tailings 1	Copper	24%	2.70
Tailings 2	Copper	36%	2.70
Tailings 3	Copper	37%	2.70
Tailings 4	Coal	34%	2.14
Tailings 5	Nickel	19%	2.65
Tailings 6	Iron	7%	3.12
Tailings 7	Iron	6%	3.42
Tailings 8	Gold	35%	2.78

The samples cover a wide range of PSDs. The full plant tailings (FPT) PSDs for the samples are shown in Figure 3. In line with expectations, all tailings samples are relatively fine. The three copper tailings samples cover the widest range in PSD variation, with the Tailings 2 sample being approximately three times finer than the Tailings 3 sample. The average D50 for the samples is 17 microns, combined with an average D20 of 3 microns. This indicates that, when properly dewatered, the dewatered streams display paste behaviour.

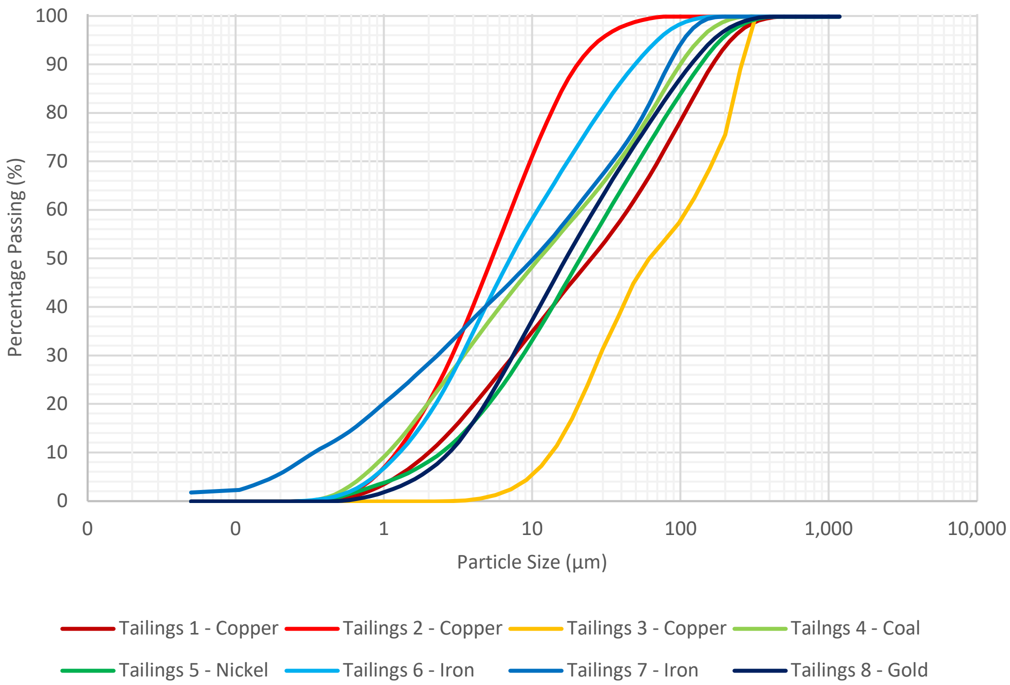


Figure 3 Tailings sample PSDs

5 Results

Each testing campaign was tuned to optimised operating conditions. The results – as compared in this study – were obtained running at these optimised settings. The primary cyclone produced a high density pCUF for all samples. Tailings 4 produced the lowest solids concentration of the tested samples, where the copper tailings on average produced the highest solids concentration in the pCUF stream. The solids concentrations in weight percentage are presented in Figure 4. The properties of the final product were mainly impacted by primary cycloning and centrifugation of the sCOF. Tailings 3 and Tailings 6 had relatively dilute cyclone underflow streams. Tailings 8 was only subjected to primary cycloning. For Tailings 8, primary cycloning produced a sand with the required draining (PSD) properties; hence, further data has not been produced. Tailings 6 is a fine iron ore tailings sample. The high solids SG, in combination with the fine PSD, affects the recovery of solids to the pCOF and, consequently, the performance of secondary cycloning.

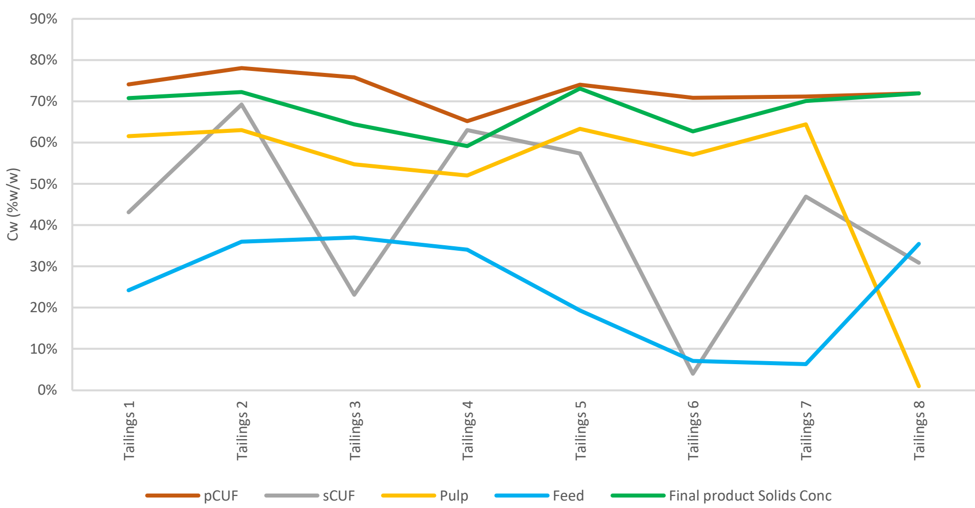


Figure 4 Solids concentration of the feed, pCUF, sCUF, cyclone feed and the final product

5.1 Solids recovery

Primary cycloning results in pCUF solids concentrations between 70 and 80% by weight (Figure 5a). Solids recovery to the pCUF fluctuates between 45 and 55%. The data indicates finer PSDs have a lower recovery and coarser samples to have higher recovery. Feed solids concentration has limited effect.

In Figure 5b, the same data is displayed for secondary cycloning. In the figure, it can be seen that the solids recovery to the sCUF is fluctuating more compared to the primary cyclone. The sCUF solids concentration is lower as a result of the finer PSD. The low solids recovery of Tailings 3 and Tailings 6 can be attributed to the relative coarseness of the first and the high solids SG of the latter sample.

The final product is composed by mixing the pCUF, sCUF and pulp together to form a paste product (Figure 6). In primary cycloning, approximately 50% of the solids are recovered. The centrifuging step recovers approximately 40% of the solids – mainly the fine fraction. The contribution of the secondary cycloning stage contributes up to 10% in the overall recovery of solids.

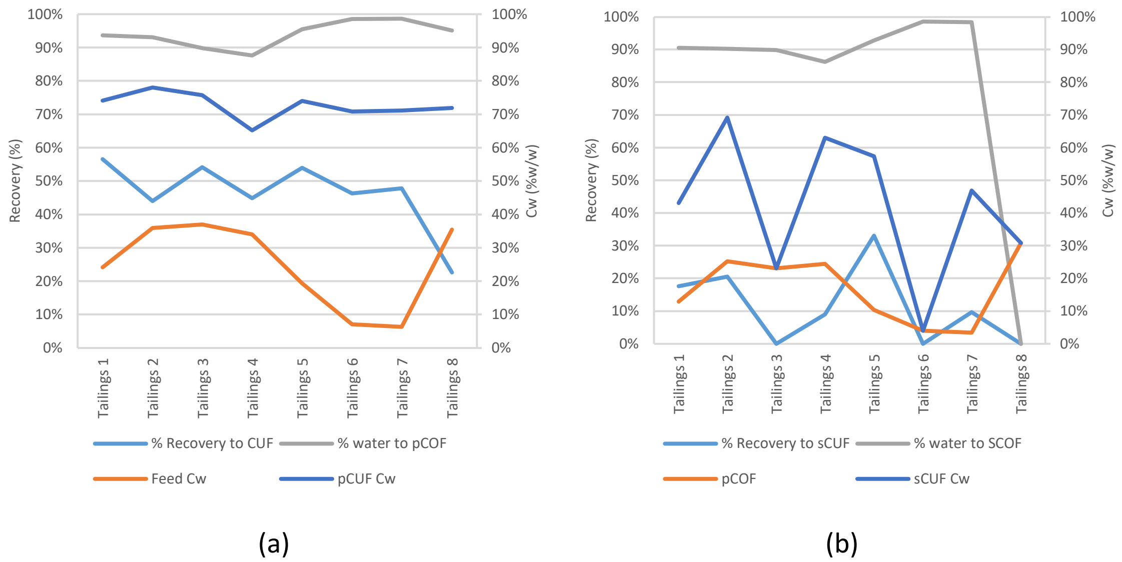


Figure 5 Solids recovery and solids concentration of streams: (a) Primary cyclone; (b) Secondary cyclone

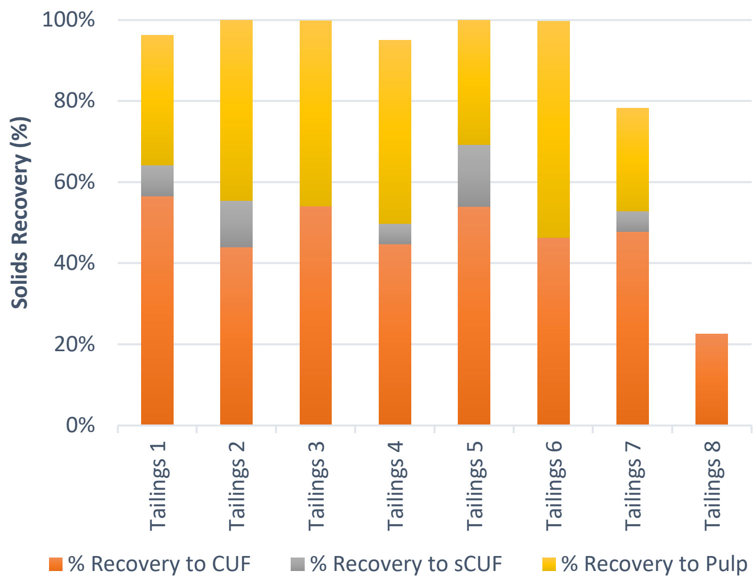


Figure 6 Solids recovery to final product

5.2 Water recovery

The preservation of water is a fundamental part of the Terraflowing dewatering process. Figure 7 presents the water balance of the three steps in the dewatering process. The high-pressure primary cycloning step ensures little water loss to the cyclone underflow. Most water is lost as interstitial water in the pulp.

On average, 77% of the water present in the feed was recovered for re-use in the processing plant. Overall, water recovery was 95 and 97% for Tailings 6 and Tailings 7; both of which were iron ore tailings. This suggests a correlation, albeit weak, between solids density and water recovery. The coal tailings sample (Tailings 4) had a relatively high moisture content of the pulp, which was likely the result of the physical properties of the organic solids in the tailings.

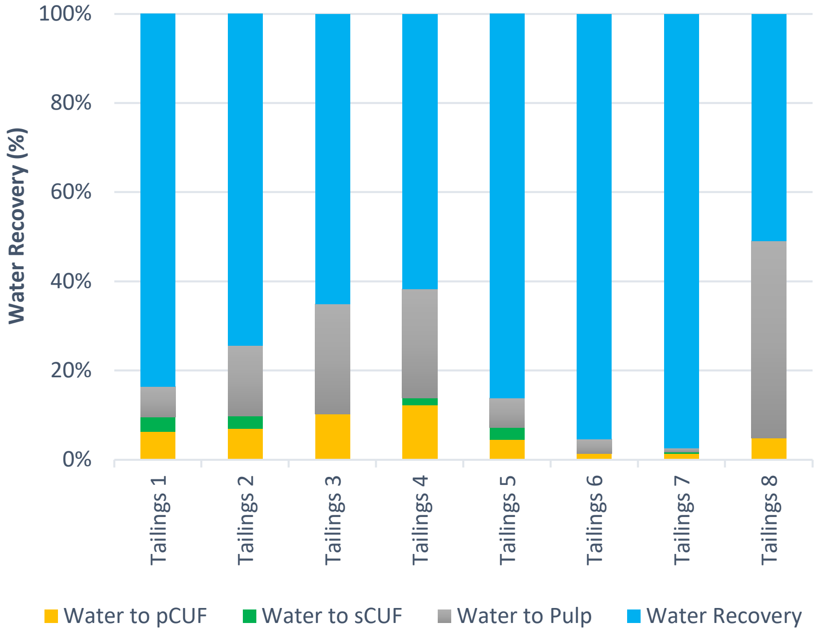
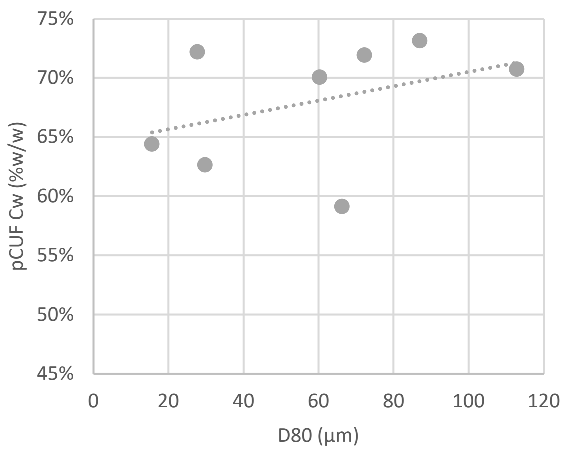


Figure 7 Water recovery

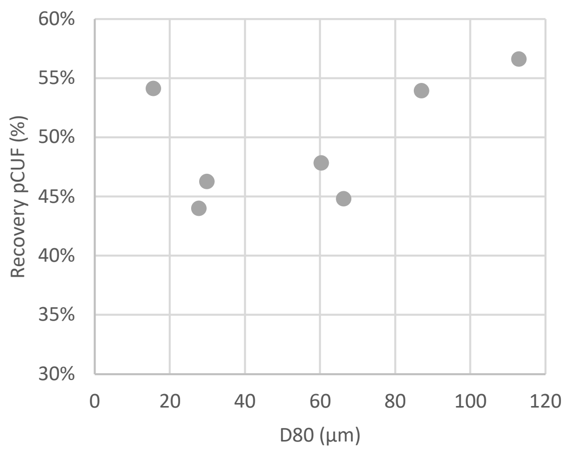
5.3 PSD variation

The particle size, represented by the D80 in Figure 8, has a slight effect on the underflow solids concentration. With increasing D80, the pCUF solids concentration increases. The D80 is chosen to represent the total PSD to allow graphical representation of the impact of variations in feed particle size.

In Figure 8b, recovery is plotted against the D80. The graph shows a trend of improving recovery with increasing D80. In this plot, the recovery data for Tailings 8 is excluded as this particular test aimed to produce a classified primary underflow product rather than maximise recovery. By consequence, the recovery for Tailings 8 was reduced as compared to the test results aiming high solids recovery.



(a)



(b)

Figure 8 Particle size effect on pCUF. (a) Cyclone underflow density; (b) Solids recovery

5.4 Feed solids concentration variation

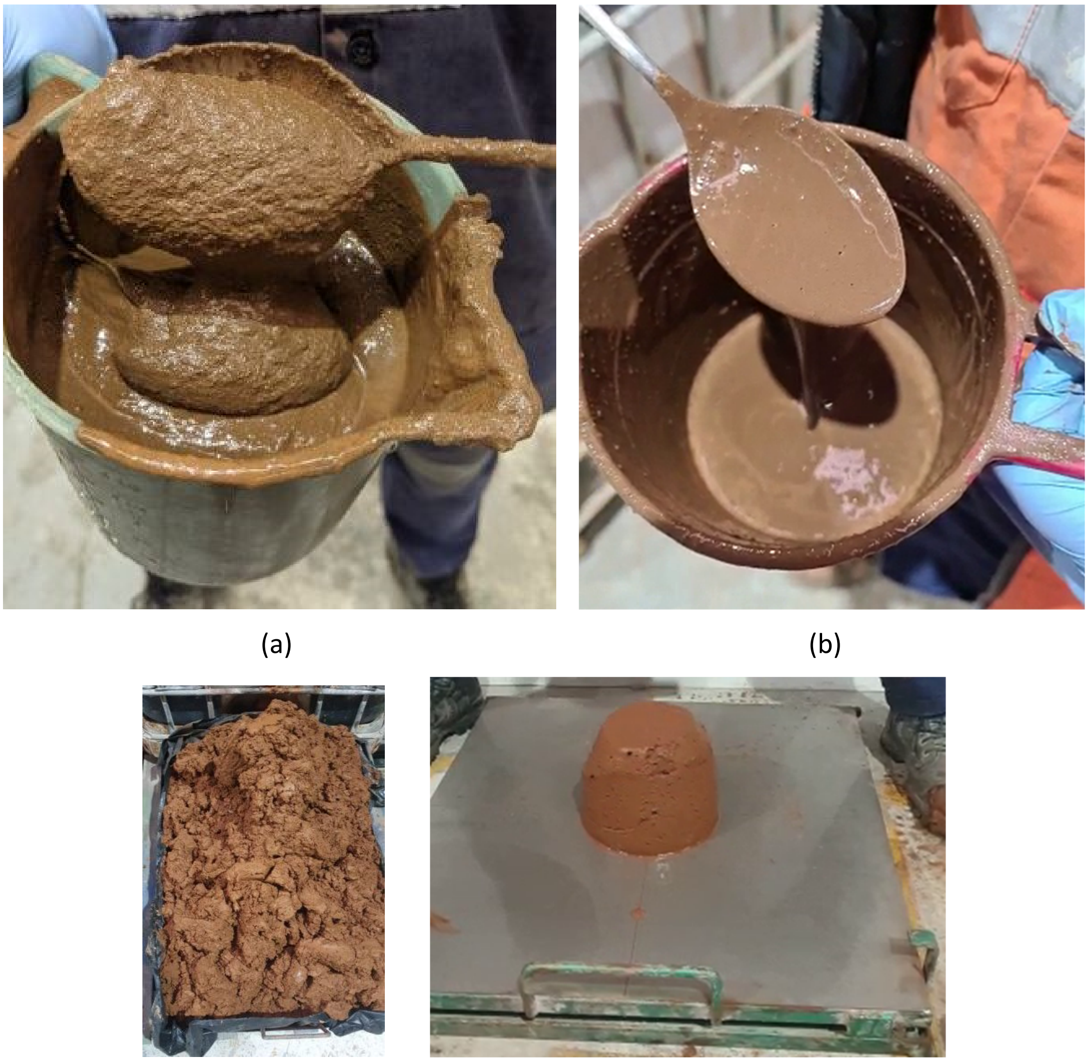
Three of the eight samples were copper tailings with comparable properties. There was a variation in the three samples of 13% by weight. The effect of this variation on the final product has been negligible for both the primary and secondary cycloning step (Figure 5).

6 Versatility of the process

Comparing the eight test campaigns shows that a tuned Terraflowing dewatering process produces consistent products. Fluctuations in feed solids concentration have limited effect on the overall solids and water recovery. Fluctuations in PSD may affect water recovery as more water might be lost through the pulp.

The process produces three products and, based on the potential use of the primary cyclone underflow stream, can be recombined to paste. An example of the three sub-streams, as well as the final product of Tailings 3, are given in Figure 9. Depending on product specifications, the cut point can be adjusted by controlling the spigot, the vortex finder diameter and the feed pressure.

Overall, water recovery of the process is high and the final product has consistent properties.



(a) (b) (c) (d)

Figure 9 Tailings 3 – copper tailings sample. (a) pCUF; (b) sCUF; (c) Pulp; (d) Combined product

7 Conclusion

The Terraflowing process is a versatile dewatering methodology that can be applied over a range of tailings and has been tested on eight different tailings samples. The testwork has demonstrated that variation in PSD and mineralogy can be dealt with by adjusting the operational conditions of the cyclone.

Comparing test results for five commodities shows that:

- Solids recovery to the primary cyclone underflow varies between 45 and 55%.
- The solids concentration of the primary cyclone underflow is between 70 and 80% for most tailings samples.
- The final product is a high-density paste with a solids concentration that is determined by the volume of fines in the full plant tailings.
- The Terraflowing process can be applied to a wide range of tailings.

References

Steward, N, Stephenson, D & Engelhardt, D 2020, *Terraflowing™ – An Innovative and Flexible Method for Tailings Dewatering*, presentation at Paste 2020: 23rd International Conference on Paste, Thickened and Filtered Tailings, Santiago.