Does thickening save water?

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Synopsis

A pilot plant paste thickening campaign was conducted at the Anglo Platinum Limited Mogalakwena South Concentrator plant in South Africa in order to determine the water saving capability of P&TT technology. In the process a simple water consumption model was developed for estimating the overall water consumption of the mine. The model indicates that for the Mogalakwena tailings, significant water savings are achieved by discharging thickened tailing directly to the TSF but only at densities where free water release at the TSF is close to zero.

Keywords

Paste, thickened tailings, thickener, water savings, water consumption.

Introduction

South Africa's lack of substantial water resources has been well publicized for decades. However, in recent years, a combination of increased urbanization and industrialization combined with the commodity boom have re-ignited concern for the long-term sustainability of the resource.

Within the Bushveld Complex, up to 46 platinum-related mines are either in production, development or in planning (Johnson Matthey, 2008). By assuming an average head feed grade of 3.5 g/t, stated production targets (for refined equivalent platinum ounces) and an average water consumption of 1.0 m^3/t of head feed treated a maximum annual total water consumption of 65 659 Mℓ is estimated for the existing 24 platinum mines operating in the Complex. This figure is likely to double should all the projects be brought to account. To put this figure in perspective, roughly 70% of the volume of the Hartebeespoort dam would be consumed every year to sustain platinum mining only.

Recent reports indicate that little to no technical high level leadership in respect of water saving strategies are forthcoming and that it is being left to individual mines to come up with solutions (Bennett, 2009). It is perhaps fortunate then that technical innovations, particularly within the last 15 years, such as paste and thickened tailings (P&TT) have revolutionized the water recovery and tailings disposal methods available to the mining industry.

Paste and thickened tailings

Although P&TT has its conceptual roots in the geotechnical field of tailings storage facility (TSF) design, its technical origins were developed within the alumina industry to reduce the volume of hazardous tailings reporting to the tailings dams (Robinsky, 1999; Getahun, *et al.*, 2000). Combining the improved thickening ability with a better understanding of transporting (pumping) and storing the thickened tailings, has allowed the concept to become a practical reality which has been implemented worldwide since the late 1990s (Williams *et al.*, 2008). Within Southern Africa, a number of P&TT facilities have either been implemented or are in development (Johnson and Vietti, 2003; Williamson, 1997). The main claimed advantages of the technology are amongst others:

- ➤ Improved water recovery at the plant and hence lower raw water consumption
- ➤ Improved TSF structural stability since no free water accumulates on the dam
- ➤ Reduced seepage to groundwater
- ➤ Improved TSF rehabilitation and reduced closure costs.

Although it is certainly a fact that water consumption can be reduced by thickening and recovering all of the water at the plant, it is also theoretically possible to reduce water

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consumption by not thickening at all, but by efficiently recovering the water released by the dilute tailings at the TSF and returning it to the plant. Consequently, considerable debate exists as to the actual water saving benefits which can be achieved by P&TT.

In an attempt to determine where the water saving benefits lie, a project was initiated by Anglo Platinum Limited which included Paterson & Cooke and SRK Consulting, to determine the water saving benefits by applying P&TT technology to the Mogalakwena South Concentrator flotation tailings.

Paste thickening trials

A paste thickening pilot plant was designed, built and operated by Paterson & Cooke and consisted of the following components:

- Laboratory/storage container
- Slurry holding tank, stirrer and feed pump
- Process water holding tank and feed pump
- Flocculant make-up and dosing pump
- 300 mm diameter paste thickener (extendable to 3 m height) and underflow pump
- Dilution tank, stirrer and underflow pump.

Total combined tailings derived from the Platreef orebody, was fed to the paste thickener after which thickened tailings were generated and the thickener operating performance was evaluated; total combined tailings consists of flotation tailings from both the IsaMill™ grinding mill and conventional ball mill circuits. The rheological properties of the thickened underflow were evaluated for pumping purposes before the flow and drying properties were determined for geotechnical purposes by SRK Consulting. The plant operation and tailings properties are presented in and Figure 1.

Thickening and rheological results

The thickening performance of the pilot plant paste thickener was demonstrated by plotting the operating point of the thickener (i.e. operating underflow solids concentration) on the sheared yield stress curve for the total combined tailings (Figure 2). The *in situ* consolidated solids concentration of the tailings in the TSF is also indicated for comparison.

It is apparent that considerable dewatering of the tailings is achieved by paste thickening, allowing the tailings to achieve solids concentrations of 70% by mass with a fully sheared yield stress of 55 Pa (Table II).

Water consumption comparison

In order to conduct an overall mine water consumption analysis, a steady state model (i.e. once equilibrium conditions have been achieved at the TSF) of the water recovered from both the Mogalakwena South Concentrator Plant and TSF was developed (Figure 3).

The model assumes a total TSF footprint area of 110 ha and includes the average yearly precipitation values for the Mokopane area.

The following plant and TSF parameters are defined:

HF = Plant head feed (t/h)

T_w = Volumetric flow rate of water in the tailings reporting to the TSF (m³/h)

F_w = Volumetric flow rate of 'freely released' water upon discharge at the TSF (m³/h)

R = Volumetric flow rate of water recovered to the plant from the return water dam (m³/h).

The water loss parameters are defined as:

E_p = Evaporation loss at the TSF pond (m³/h)

E_b = Evaporation loss at the TSF beach (wet and dry areas) (m³/h)

E_d = Evaporation loss at the return water dam (m³/h)

Sp = Seepage loss via the TSF base area (m³/h)

I_w = Volumetric flow rate of interstitial water remaining after placement (m³/h)

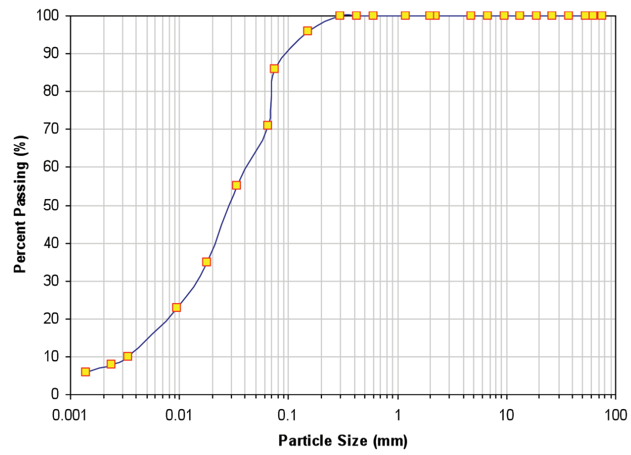

Figure 1—Particle size distribution for the total combined tailings sample

Table I

Mogalakwena south concentrator head feed and tailings properties

Mogalakwena South Concentrator feed	
Ore type	Platreef
Head feed treated (t/h)	575
Specific gravity	3.2
Total combined tailings	
Pulp density (kg/litre)	1.28
Particle size d_{50} (µm)	27
Average pH	9.1 at 21.5°C

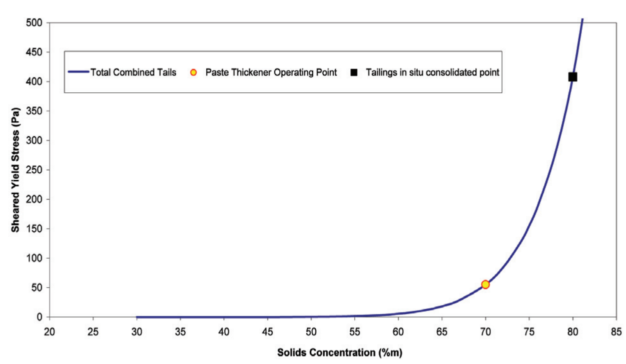

Figure 2—Paste thickener operating performance

Table II

Paste thickener operating conditions

Operating condition	Flocculant dose (g/t)	Solids flux rate (t/m³.h)	Fluid rise rate (m/h)	Underflow solids concentration (% by mass)	Sheared yield stress (Pa)
Paste thickener	30	0.6	5.6	70	55

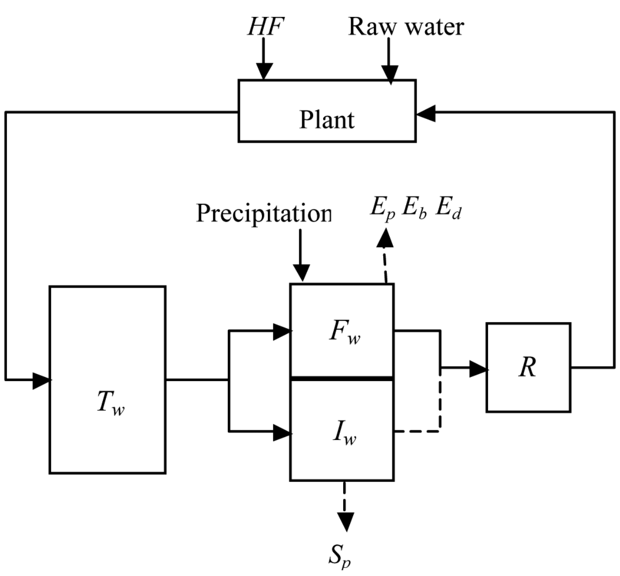

Figure 3—Mine water consumption model

I_f = Volumetric flow rate of interstitial water remaining after consolidation (m³/h).

The volume of water reporting to the TSF from the plant thickening circuit (T_W) is determined from a mass balance exercise at the plant thickeners. The volume of 'freely released' water discharged at the TSF (F_W) is determined by multiplying T_W with a water release factor (f) at the placed solids concentration.

The water release factor at any placed solids concentration is determined by constructing a water release curve for the tailings under investigation. Using flocculated tailings, a series of one-litre measuring cylinders is set up covering the range of solids concentrations desired. After mixing, the tailings are allowed to settle for 30 minutes after which the volume of supernatant water is recorded. The water release factor is calculated as a percentage of total water in the tailings freely released after 30 minutes at a particular slurry solids concentration (Figure 4).

The water release curve described in Figure 4 is unique to each tailings material and is dependent on a number of factors such as particle size distribution, particle shape, the presence or not of clay minerals, and the tailings chemical conditions.

In order to calculate the evaporative losses, evapotranspiration factors were applied to the various surfaces of the TSF according to the ratios described in Table III. The return water dam pool area was assumed to vary from 19 ha to 10 ha at placed slurry solids concentrations ranging from 34% to 60% by mass. No return water dam was assumed for slurry concentrations in excess of 65% by mass.

Seepage losses were calculated using Darcy's formula [1], for a tailings material with a permeability (k) of 1e-08 m/s where, i is the hydraulic head and A is the footprint area of the tailings dam.

$$Q = kiA \qquad [1]$$

Using the model and the parameters described above, the flow rate of water returned to the plant from the return water dam (R) can be determined in m³/h for two tailings consolidation scenarios, i.e. the initial deposited scenario ($R_{initial}$) and the final consolidated scenario (R_{final}) where additional water is released from the tailings over time as they consolidate to their final *in situ* density. The $R_{initial}$ scenario accounts only for water recoverable after losses due to evaporation. Loss due to tailings lock-up after initial placement (I_W) or seepage (S_P) are ignored.

$$R_{initial} = (T_w \times f) - (E_p + E_d + E_b) \qquad [2]$$

In order to determine the additional water recovered after consolidation has been achieved, the term (I_f) is introduced which describes the volumetric flow rate of water permanently lost to the TSF at the final *in situ* consolidated density.

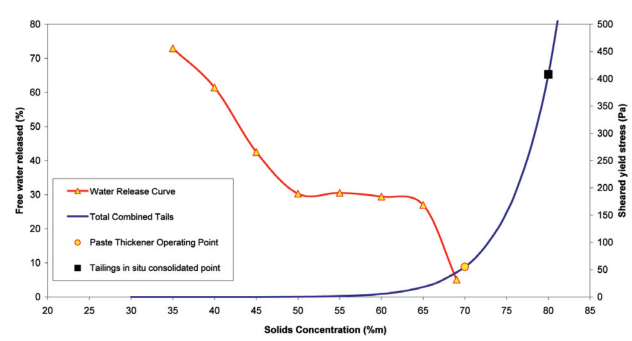

Figure 4—Water release curve for the total combined tailings

Table III

TSF evapotranspiration loss ratios

Placed tailings solids concentration (% by mass)	Per cent of total TSF footprint subject to evapotranspiration		
	Dry beach	Wet beach	Pool
Up to 42	20	65	15
42 to 52	25	65	10
52 to 60	32	65	3
60 to 69	40	60	0

$$R_{final} = R_{initial} + (I_w - I_f) - S_p \quad [3]$$

Under equilibrium conditions, an estimated mine water consumption (*WC*) in m³/t of head feed treated can then be determined.

$$WC = \frac{T_w - R_{final}}{HF} \quad [4]$$

The estimated mine water consumption for the Mogalakwena South Concentrator Plant is presented in Figure 5.

Discussion

This study presents a simple model which provides a methodology for estimating mine water consumption. Under steady state conditions any TSF will contain tailings that are both in the unconsolidated and consolidated state. The model therefore defines a range of water consumption values spanning these consolidated states depending on the density at which the tailings are placed.

Critical to the model's input is the water release curve which is unique to each tailings material as its shape determines the amount of water immediately released at the TSF and available for recovery. The volume of free water released by the total combined tailings varies as a function of placed density at the TSF. At low solids concentrations, a high percentage of free water is released (up to 73% of the water contained in the slurry at solids concentrations of 35% by mass). As the solids concentration of the tailings increases towards 50% by mass, the slurry develops a measurable yield stress. This solids concentration at which a yield stress can be measured is referred to as the gel point of the slurry and is the point at which the particles within the slurry begin to interact with one another to give the slurry strength. At this point, the percentage of free water released by the slurry appears to decrease, leading to an increase in water loss due to interstitial lock-up.

Without consolidation of the tailings, maximum water loss appears to be achieved close to the gel point solids concentration. As the tailings are thickened beyond the gel point to approximately 65% by mass, water consumption continues to fall due to: smaller volumes of slurry (and hence water) reporting to the TSF; smaller evaporative surface areas; and a relatively constant water release of 30% over this range. Thickening beyond 65% by mass, the tailings' permeability decreases to such an extent that free water release and hence evaporative losses approach zero. From 70% solids by mass onwards, a minimum intrinsic water loss is achieved which reflects the interstitial lock-up and wet beach evaporation losses only; and hence thickening beyond 70% solids by mass results in the recovery of incremental volumes of water, which have an insignificant effect on water savings.

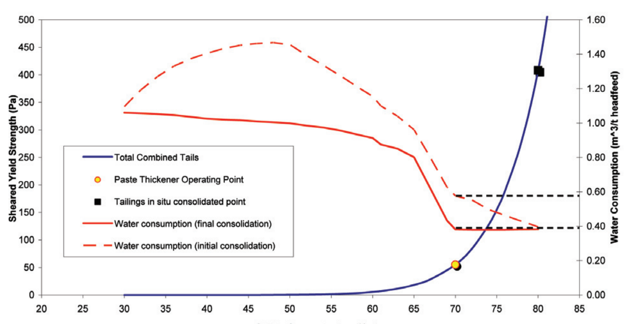

Figure 5—Mogalakwena South Concentrator water consumption curve

The difference between the initial and final water consumption curves reflects the recovery of water from the tailings due to consolidation to their final *in situ* density.

Conclusion

To return to the question posed in the title of this paper, it appears that only increasing the density of the tailings at placement (i.e. thickening) under steady state conditions saves water. Depositing at low solids concentration does not improve water consumption. It would also appear that the rate at which the tailings are able to consolidate to their final *in situ* density also plays a significant role in water savings. In this regard, high rates of rise within the TSF, particularly if the tailings are placed at solids concentrations near their gel point, appear to negatively affect water consumption. If thickening is employed, the lowest water consumptions are achieved by placing the tailings at high underflow solids concentrations where free water release upon deposition at the TSF is close to zero. Thickening beyond this point does not contribute to further water savings.

In the final analysis, it would appear that water consumption can be greatly reduced by implementing P&TT technology within the mining industry and that the technology offers a solution to economic expansion and resource sustainability.

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