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Tailings filtration toward smaller filters with higher efficiency

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Abstract

The filtration of tailings, especially in recent times given the general increase in prices, the decrease in available areas, and the ever-increasing drive towards recovery and reclamation, is becoming a race towards greater efficiency and productivity to reduce the dimensions of treatment plants and their overall costs. So, what are the improvements that can reduce machinery sizes and the project's overall costs?

First, as every site has its own characteristics, the plant must be studied in its scenario so the machines are optimised to treat the site-specific material. Test studies on cycle times and other pressing parameters are the key to designing the perfect plant for each application, reducing unnecessary losses in time and performance.

Filtration pressure is one of the most impactful variables in the process parameters. Moving to higher pressures, directly and indirectly, impacts the filtration times and therefore the overall dimensions of the machinery because it permits obtaining cake that is also better formed and less moist in less time. This change alone can significantly reduce the volume needed to treat the same amount of sludge, thus resulting in a reduction of the space required for the installation.

Another process parameter that significantly impacts the dimensions of the machinery is the mechanical time, i.e. the time that the machine needs to stay idle to perform all the required steps for its opening/closing, discharging, washing etc. Reducing these dead times is essential to improve equipment efficiency.

Other than this, the sheer amount of daily (and hourly) dry solids, which easily reach multiple thousands of tonnes per hour, is another factor that impacts this type of application. Capex and opex, as well as land consumption, are to be kept within tight limits, while at the same time, productivity, efficiency and quality of the final cake have to be as high as possible.

This is where technology plays a crucial role. Treating lots of material without losing performance is what leads to the future of a well-designed plant.

Keywords: *tailings, concentrate, filter press, silt management, dewatering, separation, environment, risk mitigation, efficiency*

1 Introduction

The demand for metals continues to grow as new technologies and infrastructures develop to meet market requests. Even though material recycling is expanding, this alone is insufficient to cover the demand. If there is one thing we can be sure about, mining businesses will keep operating for many years ahead of us (Furnell et al. 2022)

More stringent environmental constraints, driven by water scarcity and community issues, make water recycling as crucial as possible.

Because of this, systems that dewater sludge to the minimum water content, like high-efficiency filter presses, are unequivocally supplanting other types of systems that do not allow for such levels of dehydration. Compared to other technologies (e.g. vacuum filters and belt filters), filter press filtration can obtain very high dewatering levels, producing cakes with residual values as low as 20–15% w/w and even lower. Cakes obtained with this process are compact, perfectly transportable, stackable, and disposable at lower costs.

However, in current large-scale mining (updated to 2022) in dry climate areas, most typical tailings disposal schemes still consist of conventional or slightly thickened at modest levels, with tailings solids weight of up to concentration of 52–48% w/w (Cacciuttolo Vargas & Pérez Campomanes 2022).

This approach leads to problems such as large area requirements to store the thickened sludge, hydrogeological risks, high disposal costs, low water recycling and high environmental impact.

1.1 Sludge solidity stages

The operations of solid–liquid separation are usually related to water recovery for re-use in the process, adequacy of solids percentage on pulp required by the subsequent unit operations, reduction of a product's moisture for transport and sale, preparation of waste for transportation and disposal.

Figure 1 shows the correlation between using different dewatering technologies versus increasing yield stress and solid content.

Conventional tailings processing delivers slurry waste to settling ponds, which require large accessible areas and volumes. Very low yield stress is obtained.

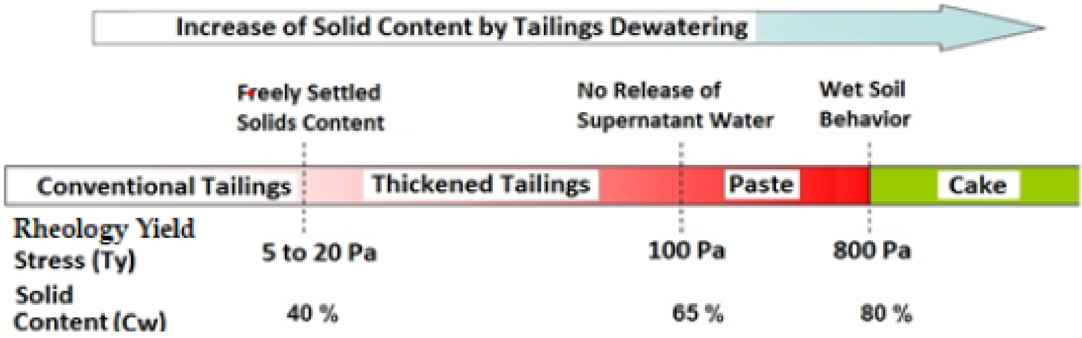

Figure 1 Levels of dehydration of sludges

Moving on to thickened tailings, high-rate rake thickeners are utilised for dewatering. This technology delivers a mud-like consistency slurry sent to ponds, but the volume utilised is exceptionally reduced from the previous case. Adding flocculating agents can increase the solidity (meant as solid content (% w/w)), but never above 55% of solids. Yield stress remains under 100 Pa.

Deep cone paste thickeners deliver a paste-like consistency (maximum 75% solids) so mine waste can be stored in tailings storage facilities. However, even in this case, the yield stress is still low to prevent risks of catastrophic failures.

In Figure 2, some of the most tragic calamities regarding tailing dams are displayed, both in past and present days (Williams 2021). Furthermore, in Figure 3, we can see the real effect of this calamities on the environment with the collapse of the Feijão dam's collapse 2019.

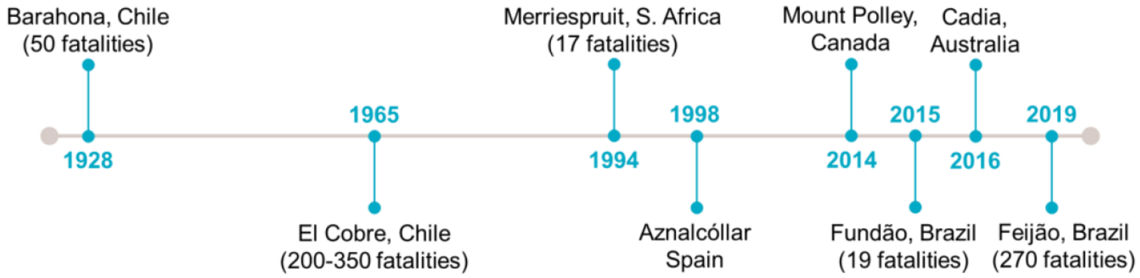

Figure 2 Major calamities caused by tailings dam failures

The 2019 Mariana disaster in Brazil brought a new focus to mining tailings disposal. The collapse of the Feijão dam released around 50 million cubic metres of sludge, killed 19 people, destroyed villages and travelled more than 600 km to the Atlantic Ocean, where it left a reddish-brown plume visible from space.

Figure 3 Feijão dam's collapse 2019

This incident raised questions about the safety of dams, leading to more significant difficulties in licensing areas for the construction of new dams, and was associated with growing public pressure and increasing proximity to residential areas in Brazil and other countries.

1.2 New challenges for the sector in Australia

In countries like Australia, with a high risk of drought and such a high concentration of natural resources and mining activities, water recovery is a decisive factor in the feasibility of new projects. Energy consumption, process efficiency, and reduction of environmental impact are generally considered the main drivers for mining companies in selecting optimised dewatering equipment for their operations.

With the increasing water scarcity, access to water has become a concern. New projects have encountered difficulties in acquiring grants for water use without a tailings management plant.

As depicted in Figure 1, filter press is the only technology to deliver a yield stress of over 800 Pa and as such, cakes are so firm and compact that they can be dry stacked and stored in a much more secure way than paste.

These cakes, which can sometimes reach a solidity of over 90%, can be transported at a meagre cost as their volume and weight are primarily solids. At the same time, all the recovered water is reintegrated into the process, reducing further operational costs. The reduction of operational costs fully recovers the price of the machinery required.

2 Process improvements

So, what improvements can be made in the industry to improve filter press technologies, reduce machinery sizes, and be more attractive for mining operations?

Studies on cycle times and other parameters are the key to projecting the perfect plant for each application, reducing unnecessary losses in time and performance.

Filtration pressure is one of the most impactful variables in the process. The higher the pressure, the lower the cycle time and therefore, the overall dimensions of the machinery are lower because it permits the cake to be obtained in less time, which is also better formed and less moist.

First of the most critical and exclusive technical developments introduced by Matec equipment is the high pressure technology. Matec filter presses work at high pressures (16 to 21 bar – 1.6 to 2.1 MPa) ensuring maximum water recovery, minimum moisture on cakes, and lower cycle time. The following figures show the effect of pressure on dehydration (Figure 4) and cycle time (Figure 5) for a given material.

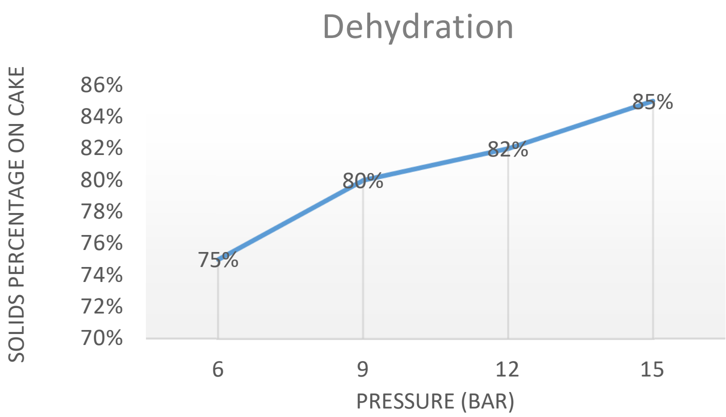

Figure 4 Pressure effect on cake dehydration

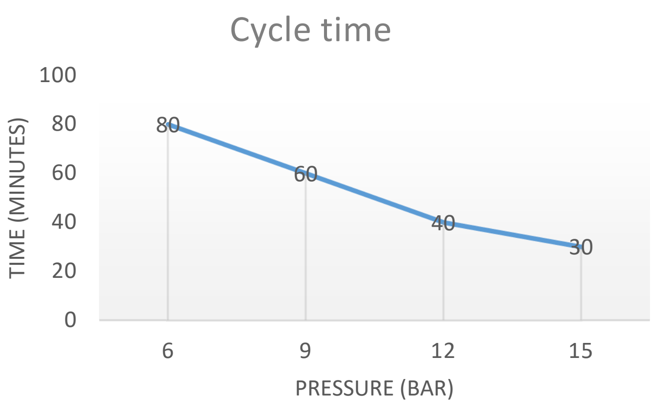

Figure 5 Pressure effect on cycle time

It is clear that for a given throughput and target TM%, a filter press operating at higher pressure will require a shorter cycle time.

This change alone can significantly reduce the volume needed to treat the same amount of sludge, thus reducing the space required for the installation. The overall benefits are as follows:

- Smaller equipment size and a smaller number of units are needed to achieve an equivalent given production throughput.

- Processing complex materials with a high proportion of ultrafine and clay without relying on the additional complexity and cost of membrane plate systems or adding chemical aids.
- Higher performance and recovery rate with a resulting TM% reduction in the cake.

High-pressure technology is specifically suitable for applications with a high proportion of ultra-fines and clay commonly associated with tailings and increased by the crescent exploitation of deposits with lower metal content.

Ultrafine particles in the range of 0–30 um and clay are challenging in the filtration process, as they tend to blind filtering media, creating an impermeable layer that decreases or even limits the dewatering process. Thanks to the higher pressure over 16 and 21 bar, it is possible to break through this material layer, forming into the filter chamber at the very start of the filtration phase and thus completing the dewatering process and producing dry stackable cakes (Figure 6).

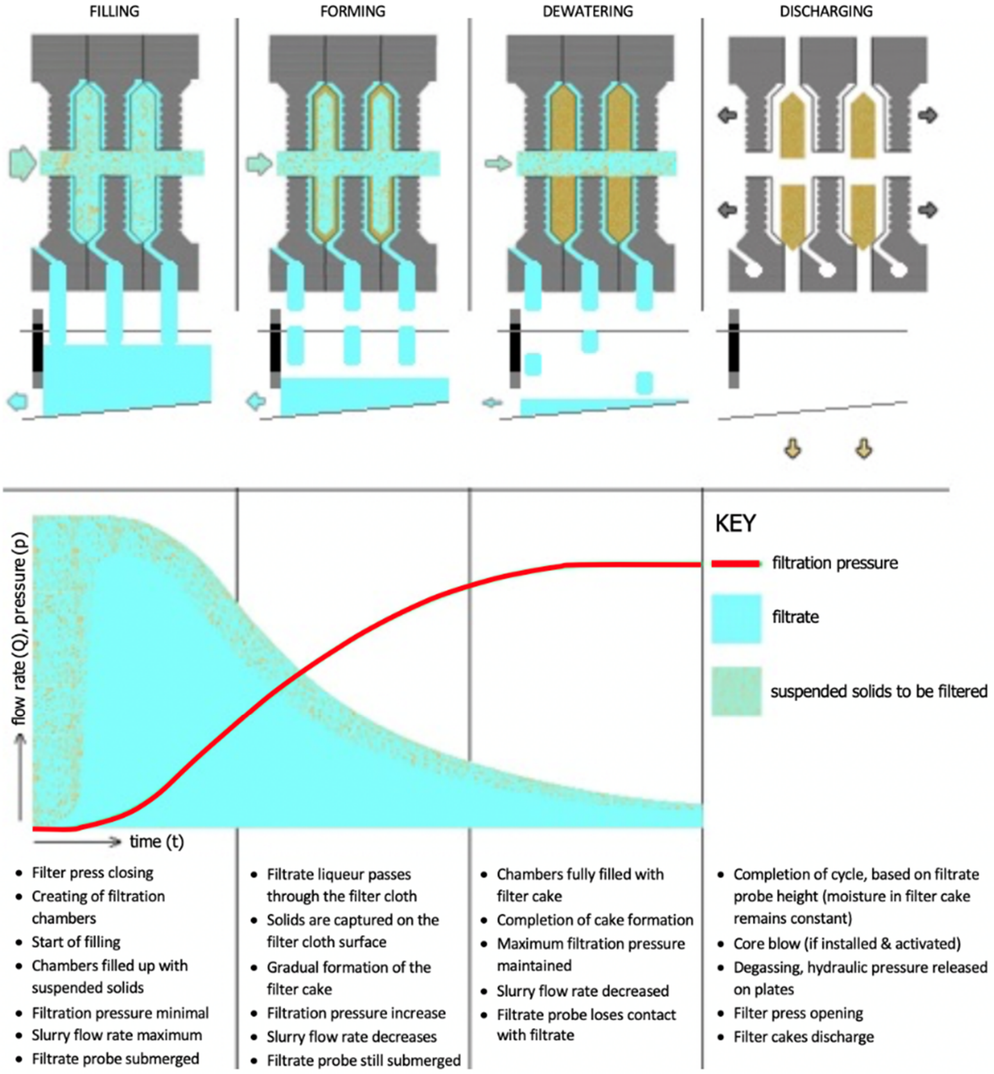

Figure 6 Matec plate filter dewatering process phases (2018)

Another process parameter that significantly impacts the dimensions of the machinery is the mechanical time, i.e. the time that the machine needs to stay idle to perform all the required steps for its opening/closing, discharging, washing etc. Reducing these dead times is essential by studying new ways to operate the machine and discovering new technologies that speed up the process without losing performance.

The second of the most critical and exclusive technical developments introduced by Matec equipment is the TT2 Fast Opening®. The filter plates' fast opening system ensures lower dead time between cycles, reducing the opening time of the machine from the typical 20–25 minutes to approximately seven minutes even for the larger 220-plate machines and consequently achieving more productivity. The systems are automated, controlled by PLC and easily integrated into the existing plant.

A faster opening of the plates, for example, will lead to a shorter cycle time and a smaller filter press for the same application. By opening 10 plates at a time instead of one by one, the discharging time is reduced by one-third and if, while opening 10, the 10 before them are being closed, this time will reduce even further. This technology employs lateral hydraulic cylinders that pull on the first plate of every pack, effectively opening the whole pack and closing the one before it in just 20 seconds (shaking the plates to ensure a proper detachment of the cakes included).

Matec filters recover the maximum amount of water for re-use and reduce moisture to minimum levels in the concentrates and tailings, ensuring the lowest possible operating cost and lower power consumption.

Matec filtration systems can be generally composed of (refer to Figure 7):

- Raw water tank: receives the tailings and slimes from the beneficiation plant and conditions and pumps to thickeners.
- Submersible pump: lifts the slurry in the dirty water tank to the thickener.
- Matec deep cone thickener: combining the thickening and clarifying functions, it delivers an underflow with 50 up to 65% solids and a reasonably clarified overflow. It requires a relatively small installation area and has no moving parts inside. No motors, rake, bearings or extraction pumps. Alternatively, a high-rise rake or rake paste thickener can be deployed for a very large process flow rate.
- Automatic dosing, preparation, and flocculant analysis station. It mixes the polymer powder with water, makes tube tests and automatically adjusts the dosing of flocculant into thickener.
- Homogeniser tank: receives the underflow slurry from the thickener and keeps it homogeneous until pumped into the filter press.
- High-pressure single, double, and triple cavity centrifugal pump: extracts the dense pulp from the homogeniser tank and presses it into the filter. It is controlled by a variable-frequency drive.
- Matec filter press: after the plates are closed by a hydraulic piston, the pulp is pumped into the filter, filling all the chambers formed by the union of the plates. Pressure forces the filtrate through the cloths and the drainage ducts while the solids remain retained. After the cycle, the feed pump stops and the plates open to discharge the cakes.

Figure 7 Matec filtration plant in Brazil 2019

3 Test work and customisation

Testing the material is crucial in filtration as every mine has its characteristics and needs. Therefore, a customised plant accounts for various factors determined before plant sizing and scaling.

Results obtained with pilot equipment are fully scalable to every type of plant, regardless of its production and dimensions, because it can recreate all the conditions of the plant and has all the options that a full-scale machine could have.

Figure 8 Matec FP400/10 test rig in Perth, Western Australia

As shown in Figure 8, a typical test work regime and procedure include placing thickened slurry into a homogeniser tank that keeps the solid particles in suspension.

A review of process conditions, particle size distribution, and solid gravity is completed to decide the type and set-up for the filter press system to be utilised. The main parameters measured during test work are:

- Cake thickness
- Filtration time
- Mass of filtrate over time
- Cake moisture.

Based on test work results, the plant's design can finally commence.

4 Case studies

Besides test work campaigns, experience is at the base of projecting a plant that works perfectly. In this section, we will report three case studies related to existing plants. Three different but equally important aspects of tailing filtration will be highlighted.

The Companhia Siderurgica Nacional (CSN) plant in Brazil is a plant that underwent three expansions and is perfect for understanding the relationship between machinery and production, as well as comprehending how a project develops.

Consorcio Peña Colorada in Mexico is presented to describe how implementing larger machines with latest-generation systems reduces mechanical times, increases productivity and reduces the space needed for the installation.

Lastly, a plant in Brazil will be described from a cost-related point of view to analyse the benefits of installing filter presses and producing cake-like consistency waste versus using only high-rate rake thickeners and managing huge volumes of mud.

4.1 The Companhia Siderurgica Nacional plant in Brazil

Starting with the CSN case study, this project was divided into three stages to increase production and keep up with the mining operations. First, the plant needed to treat 550 tph waste tailings from an iron ore mine. Matec installed two vertical high deep cone thickeners and four filter presses FP2000/190 plates for this first phase. The plant was then expanded by adding five more filter presses of the same size and three more vertical thickeners to cover a further 650 tph production, bringing the overall plant total throughput to 1,200 tph. For the final target of 35,000 tonnes per day of tailings to be dewatered, an additional 40 m diameter high-rate thickener and two more filter presses were also implemented in the plant, bringing the total to 11 filter presses with an hourly output of almost 1,500 tph, making it one of the largest mine waste treatment plants in the world (Figure 9).

Figure 9 Companhia Siderurgica Nacional plant completed with the final expansion

This project has allowed several square kilometres to be cleared of mining sludge ponds, making it safer for those who work there and limiting the environmental impact of the occupation of land for these activities for the benefit of personnel and mine operations.

4.2 Consorcio Peña Colorada

A tailings management plant can sometimes occupy space. As such, it is of great interest to explore solutions that can also reduce the machinery footprint, effectively decreasing the land consumption for dewatering operations.

The rendering of the plant design for the Consorcio Peña Colorada tailing plant is shown in Figure 10. This project aimed to dewater sludges from an iron ore mine, roughly 450 tph. The solution proposed for this plant was the installation of six filter presses FP2526/190 plate size with five machines on duty and one on standby to cover the maintenance schedules.

In this case, using much larger machines with high-pressure technology and fast opening cycle time has improved the efficiency of the overall project, thus reducing the real estate required from the initial scope to nearly 30%, minimising cost and avoiding expansion of the site.

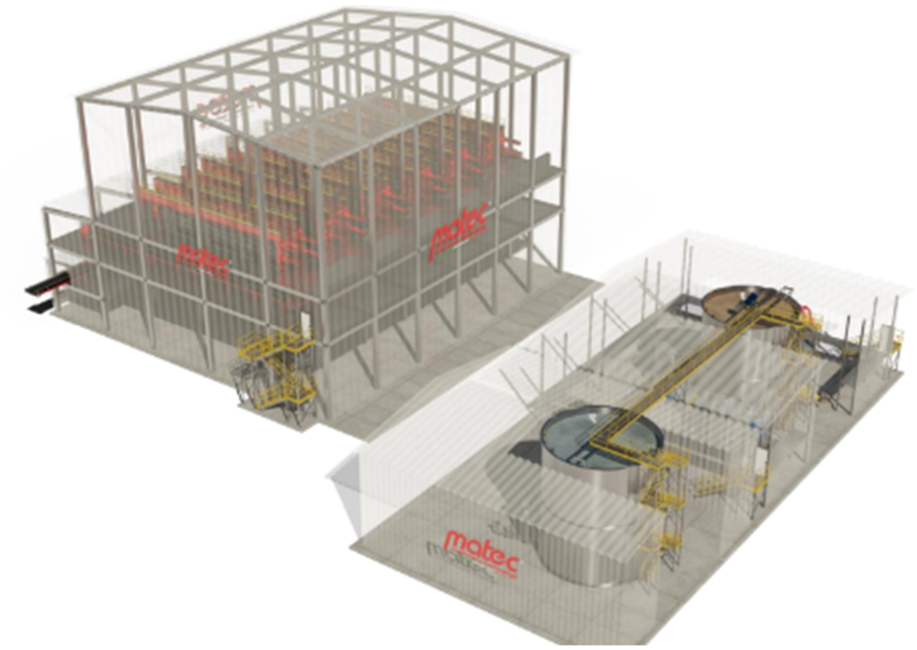

Figure 10 Rendering of the plant under construction with six high beam filter presses 2500 × 2600 and 190 plates

In addition, the solution has been perfectly optimised from the point of view of mechanical time and cake result, implementing systems such as drying with compressed air, which reduces residual moisture in the cakes (and therefore the volume required for the same production), automatic washing of the cloths, which minimises the time needed for washing the entire machine, which is effectively dead time, provided it is necessary for the correct operation of the equipment, and very high flow loading pumps, which influence the filling time before filtration itself.

Given that the filtration and air-drying time of this type of material is extremely short, usually no more than six to seven minutes in total, the reduction of machine time in all its phases (opening/closing, unloading, washing etc.) is significant, especially for machines of this size, that usually take more than 10 minutes for all the above-listed operations. It's easily understandable that reducing idle time to the minimum possible, which is longer than the production phase, namely filtration, is crucial to increase efficiency and reduce cost.

4.3 MML Mineracao

The last case study presented is a plant again located in Brazil, which is symbolic of deeply understanding the different operational costs of running a plant that produces waste in the form of thickened sludge versus dry stacking.

This original plant design consisted of several paste thickeners, which could not treat all the material from the mining operation. Additionally, paste thickeners could only reach a paste consistency of the resulting mud, still containing a high moisture value of 30–35% and limited competency.

Two Matec HP filter FP2000/120 were installed to replace the thickeners, which are capable of treating up to 125 tph of dry solids. Considering that the present thickeners were capable of only 6 tph each, 21 units would have been required to achieve the same productivity.

Comparing the operating costs of the units alone, then those related to the electrical supply, it is possible to calculate the mere annual savings that the installation of the two filter presses provided compared to the thickeners. This calculation also doesn't take into account the fact that the cake residual moisture coming out of the filter press is way less than that of the mud coming out of the thickeners, so there was also an improvement in sludge transportability/stack ability, reducing, therefore, costs related to the operation.

Data on the power consumption and its relative costs and yearly savings are reported in Table1.

Table 1 Power consumption costs of the two solutions

Equipment	FP option	Paste thickener option
No.	2	21
Total power (kW)	526	3,366
Power cons. (kW/h)	287	2,111
Total annual cost (R$)	723,182	5,319,864
Yearly savings (R$)	4,596,682	

5 Conclusion

This paper presents technological advancements and improvements in tailing filtration that are being implemented to reduce costs and land requirements while preserving the environment from the increasing production of mineral wastes.

Reducing cycle time has the dual benefit of reducing the size of the equipment required to achieve a target throughput and, as such, reducing both the capital cost for the equipment as well as the footprint and overall operational cost per ton of material, compared to lower feed pressure technologies and other technologies generally in use in the mining dewatering operations.

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