CLAYS CONTAINED IN MINERAL ORES AND THEIR EFFECTS ON SOLID-LIQUID SEPARATION PROCESSES

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ABSTRACT

Dry stacking of filtered tailings usually requires a low cake residual moisture to meet the specifications from geotechnical engineers. The growing demand for minerals has resulted in lower and more complex grades of ores being mined and processed. Many such ores contain varying amounts of clays. The filtration process can be hindered by the presence of clays and it's important to understand the filtration characteristics of these ores at a very early stage in the flowsheet design.

Other solid-liquid separation process can be affected by the presence of clays, including thickening. Thickening, even in the beneficiation stage, can be severely compromised, leading to lower process efficiencies downstream (e.g. leaching). Poor thickening performance caused by non-ideal mineralogy (particularly clay content) can force the process designer to consider filtration as a more appropriate solid-liquid separation option (in some cases, even replacing counter-current decanting thickeners).

Some clays affect solid-liquid separation processes more than others. A comprehensive characterization of the ore that includes detection and identification of clay types is important. Standard physical-chemical characterization of mineral slurries includes tests for density, solid concentration and solid (and liquid) specific gravity. More thorough characterization can include tests for yield stress, particle size distribution and morphology, as well as element analysis and mineral phase detection. Some of these tests require sophisticated instruments and highly-experienced technicians.

Phyllosilicates (clays) are one of the most common components of mineral ores and tailings, together with quartz, feldspar and other aluminosilicates. Their content is not necessarily predominant but their presence, even in small concentrations, can influence slurry behavior and filter cake permeability and moisture content. A comprehensive study of clay detection and quantification, including correlation with dewatering properties was recently carried out by Diemme Filtration's R&D laboratory. Some of the results and conclusions of that study are presented here. The paper also uses real project examples to illustrate how the presence of clays in mineral ores can change the flow sheet design and influence the sizing of filtration equipment.

Keywords: solid-liquid separation; thickening; filtration; dry stacking, mine tailings, filter presses, clays; beneficiation; leaching

INTRODUCTION

Dry stack tailings (DST) management offers a more sustainable and safe solution in many situations than conventional slurry storage (by ‘dry’, we actually mean filtered cake which contains moisture but within a certain limit). Mining sites where dry stacking is used are increasing and many projects with very high throughput needs are currently under operation or development. The attention of the mining sector towards the sustainability of the process, combining minimisation of risk of failures, environmental footprint and maximum water recovery is pushing the development of this strategy and related technologies. To achieve the best practice level, the creation of partnerships between mine owners, engineering companies and equipment manufacturers has been essential.

One critical aspect of filtered tailings storage is related to the economical assessment of the overall process. This topic is much debated in the mining industry, mainly because of the high complexity of the variables involved and the related uncertainly. Cost of tailings dams are often underestimated and the benefits of DST at the time of site closure are not taken into proper consideration. The acceptance of the DST process as a viable option is largely dependent on a simpler (and short-sighted) cost evaluation, placing all emphasis on the CAPEX and OPEX of the particular design.

Currently, for DST, the use of a filter press for tailings dewatering is the most popular technology, combining substantial flexibility in regard to the variation of slurry characteristics with very high throughput capability and final cake moisture achievable. The high level of customization offered by this technology to match the slurry characteristics and final cake moisture target is a distinct advantage. However, to avoid excess capital costs, care must be taken to ensure that thorough testing is done so that the optimum plate pack configuration is selected, rather than a more expensive configuration (possibly leading to a larger filter sizing) that may be uneconomic.

The set-up of a filter press process involves many different variables, such as:

- Plate type: recessed (i.e. fixed volume) or membrane (i.e. variable volume, allowing cake consolidation by pressure squeezing), chamber thickness
- Feeding (and, in some cases, squeezing) pressure
- Application of compressed air blowing to achieve cake desaturation, and optimization of air consumption
- Filter cloth selection

Any one of these items can have a strong impact on both OPEX and CAPEX of the equipment. Use of membrane plates instead of fixed-volume ones, for example, presents a significant higher cost but can be necessary in order reach the required cake moisture. The use of compressed air blowing is often necessary to prevent liquefaction and to reach a specified cake moisture level, but the compressor and its energy demand can increase the costs capital and operating costs significantly.

In figure 1, below, a graph showing the typical moisture range achievable with different filter configurations on copper tailings (the same application as the case study discussed later in the paper) is reported. It clearly shows the importance of the target definition for a proper process configuration.

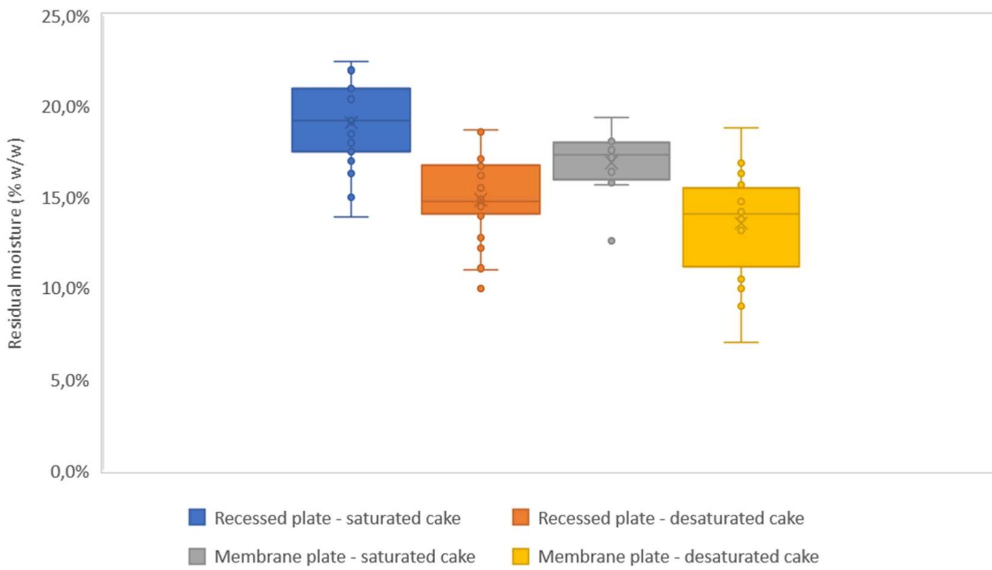

Figure 1: cake moisture vs dewatering process for different copper tailings

The material physical-chemical characteristics have a strong impact on the performance achievable, both in terms of throughput (by affecting the filtration time), and cake moisture. Each parameter has its own contribution, and this makes a full understanding of the system challenging. The particle size distribution plays an important role, considering that the building of the cake determines many process outcomes such as filtration time, cake permeability for cake blowing (desaturation), and the final moisture content of the cake. Figure 2, below, shows clearly that that generally, materials with a coarser particle size distribution form drier filter cakes (but its very important to know what the P10 of the distribution is to be able to predict cake permeability with confidence).

Another important feature that can affect the filtration performance is the mineralogy. This determines the particle shape and the way they pack to form a cake. This is particularly important for the fine fraction (below 4 microns), because of the presence of phyllosilicates. These are characterized by a plate-like structure and can contribute to a very high specific cake resistance, causing long filtration times and higher residual moistures. The worst case occurs when swelling clays (i.e. smectites) are present. Their impact is substantial from the geotechnical behaviour to the filterability of the material, leading to stricter moisture targets and lower dewatering efficiencies. Figure 3, below, shows an example from a case study comparing two different copper tailings coming from the same mine but taken from two different parts of the ore body. Both contain a significant amount of clay but sample A presents no smectite phases. However, sample B has a smectite content of around 2% w/w. The impact on proctor compaction and filtration time (considering two different chamber thicknesses) are evident.

With the rising global demand for minerals and the reduction of average mineral grade, mining and minerals processing industries are encountering progressively many more complexities. For these reasons, as in the case of copper production reported in the following figure, the demand for copper has continued to rise over the decades as new technologies evolve thereby impacting ore production. The result of this confluence is an increasing amount of tailings generated that must be managed by stressing existing structures.

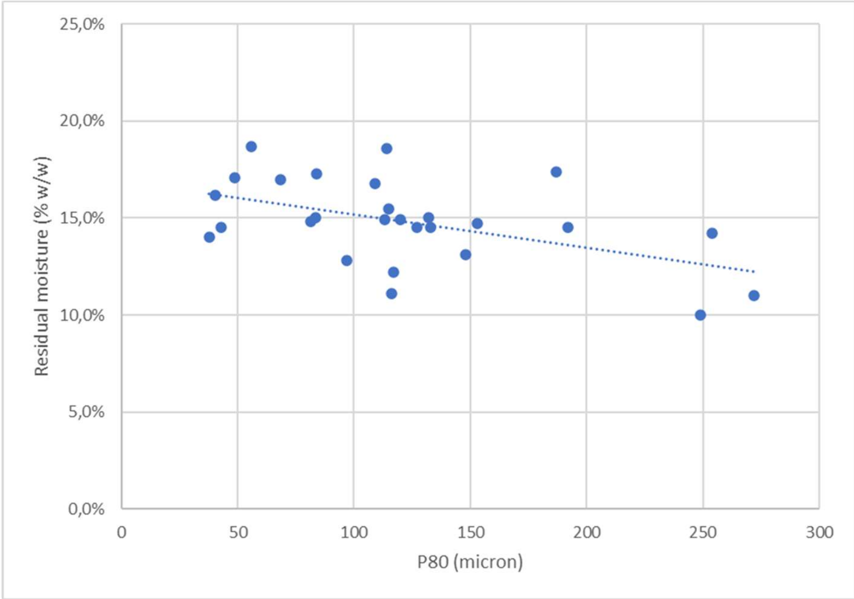

Figure 2: cake moisture vs P80 for different copper tailings

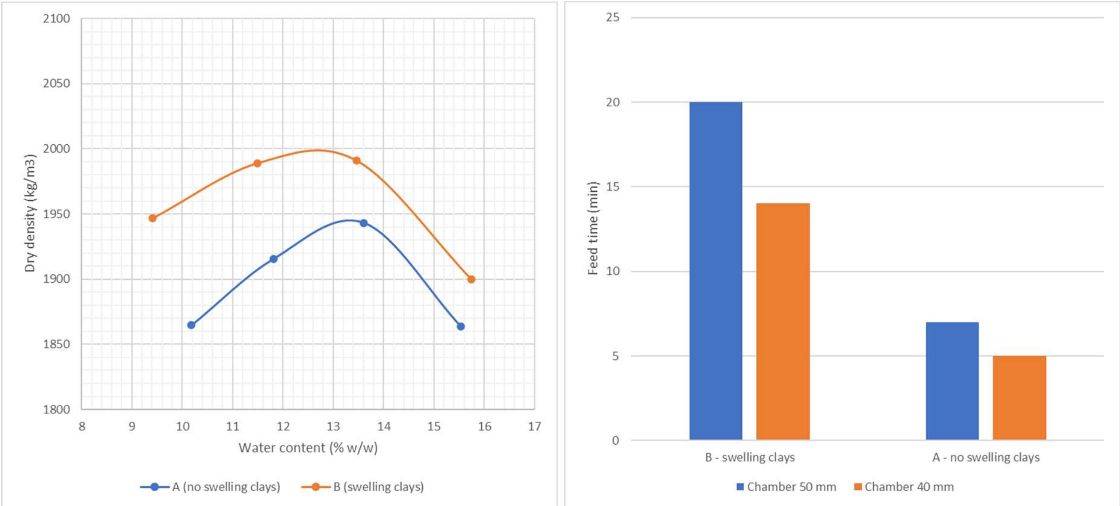

Figure 3: proctor curves and filtration times of two copper tailings with different swelling clays content

In the following section, a case study is presented, describing the strategy behind the design and sizing of the dewatering equipment and how all these aspects are involved.

CASE STUDY AND METHODOLOGY

The case study presented here is related to the design and installation of the first Diemme GHT.5000.F Domino in the SPCC Toquepala copper mine in Peru. This filter press is the biggest currently available, capable of reaching a filtration area of up to 25 m^2 and a total volume of up to 600 liters per single chamber, with a plate size of 5000 x 5000 mm. This filter has been especially developed for high capacity tailings dewatering plants, typically higher than 35,000 tonnes per day of dry solids.

The unit is part of a demonstration plant built to evaluate the use of stacking filtered tails in place of the current thickened-surry tailings dam. The demonstration plant capacity is nominally 8,000 tonnes per day (although higher throughputs have been achieved) and the required cake moisture, based on geotechnical studies and dry stack design needs, is below 15% w/w. The next step will be a full-scale plant with an overall capacity of 80,000 tonnes per day.

The filter sizing was based on the findings of detailed bench-scale filtration tests, carried out in a laboratory. A summary of the main findings and the sizing, commissioning and start-up of the industrial filter will be presented in the next session.

RESULTS AND DISCUSSION

The main results of the tailings characterisation are reported in table 1, below.

Table 1: Tailings characteristics

Slurry data	Particle size distribution	Elemental analysis	Phase analysis
Density = 1.54 Kg/l	P10 = 2.65 μm	SiO2 = 42.8%	Quartz = 41.8% w/w
Solid content = 56.0% w/w	P50 = 22.0 μm	Al2O3 = 14.0% w/w	Chalcopyrite = 1.02% w/w
	P80 = 153 μm	Fe2O3 = 4.6% w/w	Muscovite = 55.2% w/w
		SO3 = 4.03% w/w	Clinochlore = 1.9% w/w
		K2O = 3.74% w/w	
		Others <3% w/w	

The characterization data are useful to guide the initial configuration of the test filter. The tailings sample shows an average-to-coarse particle size distribution, with presence of fine sand and silty-clayey fractions. The amount of phyllosilicates is relatively high but there's no evidence of the presence of swelling clays, therefore the slurry is expected to show fast filterability and the cake will most likely be permeable allowing desaturation (with compressed air) but also well consolidated. Taking all this into account, the first stage of testing was focused on the plate/chamber configuration.

The following different configurations were tested:

- Recessed chamber filtration with different feed pressures
- Membrane chamber filtration with final squeezing with different pressures
- Addition of cake blowing in both recessed and membrane options

To simulate the filtration process, a bench pilot filter has been used. This equipment was designed by Diemme Filtration to produce results that can be scaled to any possible industrial filter setup, no matter how large. The bench filter, shown in figure 4, below, consists of one single filtration chamber with a filtration area of 0.0077 m^2 connected to the feed tanks. Figure 5, below, reports the results of the first test campaign.

Figure 4: Diemme filtration bench rig

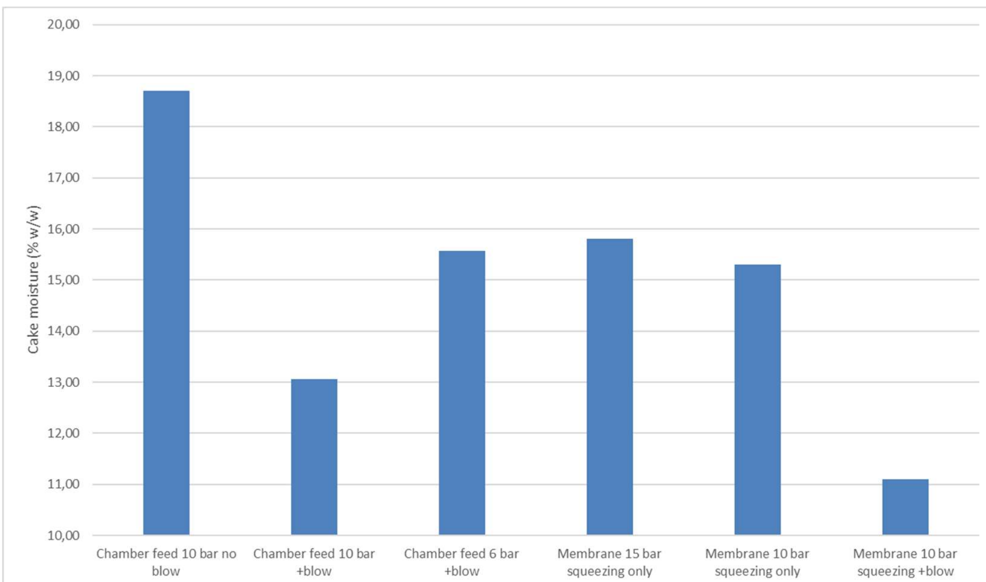

Figure 5: preliminary test campaign results

The best results were obtained using cake blowing, both in the recessed and membrane configuration. Considering that the fixed volume chamber option is significantly cheaper than the membrane (variable-volume chamber) one, and that it reaches the desired moisture, it can be considered as the best one in terms of cost effectiveness. The second stage of the of testing focused on optimizing the blowing phase with a recessed configuration, considering the blowing time and air consumption as variables (see Figure 6, below). The selected chamber thickness was 50 mm to maximize the filter throughput; thinner chambers were not required in this case as there was good cake permeability.

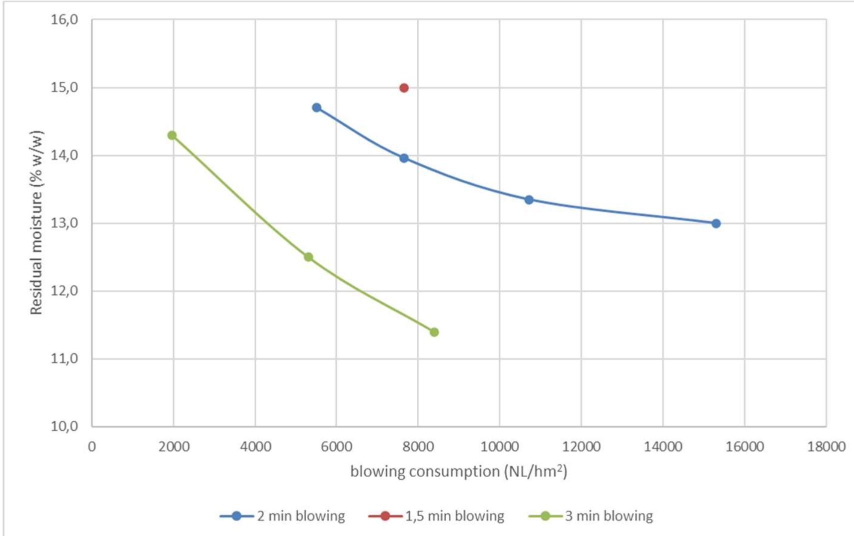

Figure 6: optimization of blowing phase in recessed configuration

Based on these results a blowing time of two minutes has been considered. The final sizing is based on the cycle time reported in table 2.

Table 2: cycle time

Cycle phase	Time (min)
Filter filling	2.0
Cake compacting	3.5
Cake blowing	2.0
Non-process time	8.0

The sizing resulted in one GHT.5000.F Domino equipped with 141 plates, with a total filtration area of 2850 m^2 and a total chamber volume of 71 m^3. It is designed to reach 8000 tonnes per day of solid throughput. The installation of the filter at site was successfully completed in less than three months. After this, the commissioning and ramp-up phases lasted for other three months each. Pictures of the Domino filter press and the overall demonstration plant (where it is possible to see the dry stacking) are reported in Figures 7 and 8.

Figure 7: GHT.5000.F Domino operating at Toquepala mine

Figure 8: Demonstration plant

An important feature of the filter press is the implementation of the AIDA system, the software developed by Diemme Filtration for remote process monitoring, support, and maintenance by means of data collection and, most importantly, data analysis. The AIDA system has been a vital tool in assisting the fine process tuning and filter optimization. The first results are very promising, Figures 9 and 10 report the data taken from AIDA showing how the filter is matching the required performances both in terms of hourly productivity and cake dryness.

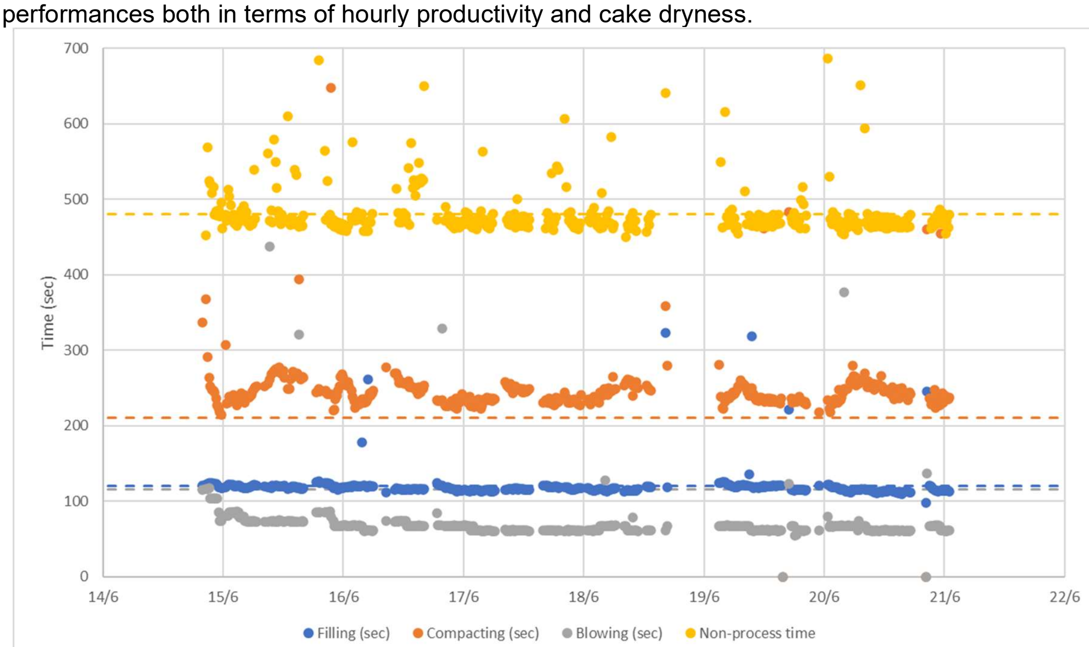

Figure 9: cycle time (different phases). Points are data coming from AIDA, dotted line are related to the sizing parameters

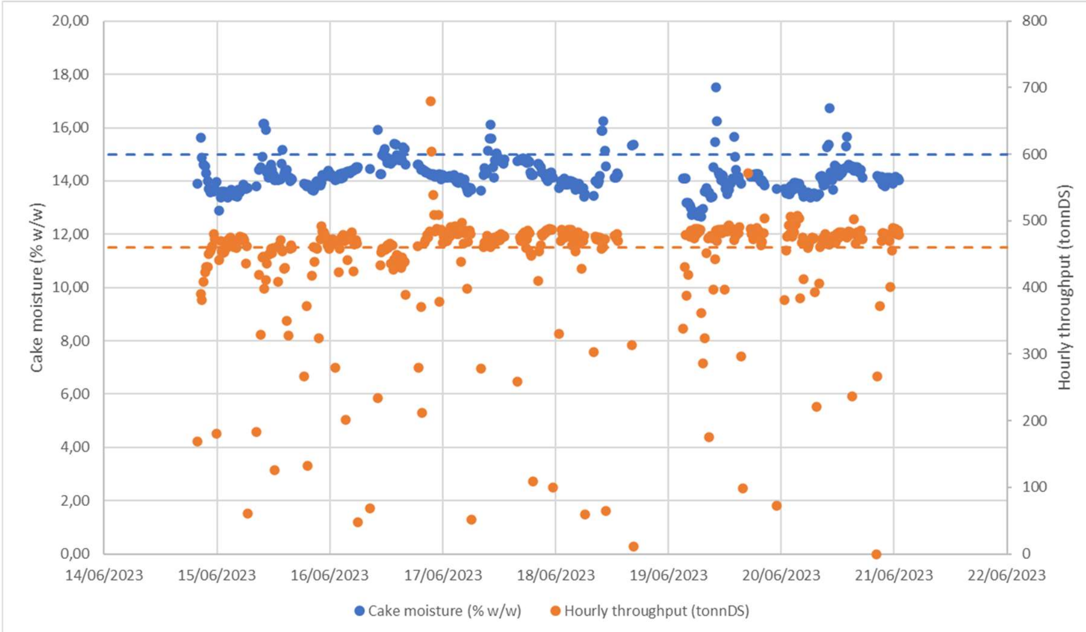

Figure 10: hourly throughput and cake moisture. Points are data coming from AIDA, dotted line are related to the sizing parameters

In figure 10, a trend of the total throughput obtained during the first week of continuous operation is reported. By means of a constant monitoring of the process parameters the cycle time and the overall availability of the filter have been optimized showing an increasing trend of the total productivity that is currently close to 10,000 tonnes per day. This optimization stage is focusing mainly on the cycle phases (particularly the blowing time) and the filter availability.

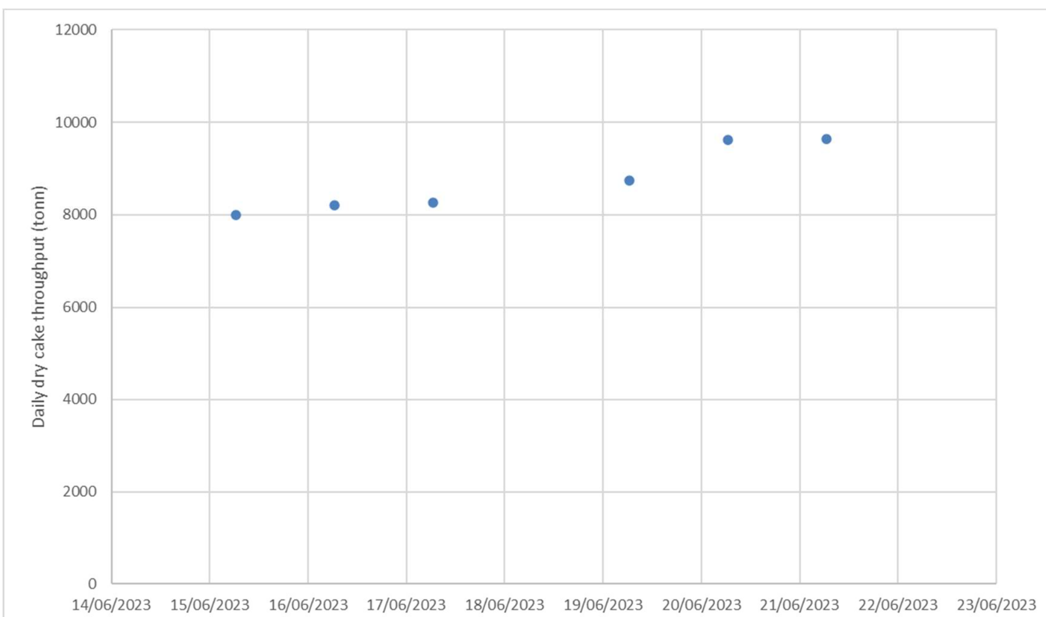

Figure 11: daily throughput

CONCLUSION

The perspectives of applying dry stack disposal for big sized projects (with throughputs overcoming 100000 tonnes per day) are increasingly promising. The related costs of this technology are still an important cause of debate; the development of the new dewatering equipment with increased capacity and optimized CAPEX and OPEX related, together with a thorough study of the process and the material characteristics carried out case by case are of upmost importance during the economical assessment of the projects.

The installation of the first GHT.5000.F Domino filter press, here presented, leads in this direction. The successfully operation of the demo plant will be an important step to demonstrate the environmental and economical sustainability of the dry stacking applied to large mining plants. The first results and feedback coming from the plant are very positive. The findings coming from the material characterization and process study and the use of real time data monitoring have proven to be vital in the optimization process.

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