

Dewatering Tailings for Dry Stacking: Rapid Water Recovery by Means of Centrifuges

Robert Klug¹, Adalberto Rivadeneira² and Nils Schwarz^{3*}

¹Flottweg SE, ***, Germany

²Consultor en Process Metallurgicos, Buenaventura, Peru

³Schwarz Global Consulting, Johannesburg, South Africa

*Corresponding author: nils@sgconsulting.co.za

At present, most tailings are dewatered by static settling in tailing dams. The environmental impact of these large settling ponds is dramatic, not to mention the space requirements and the potential risk of dam failure. This method of disposal also results in the loss of process water due to evaporation. This can be significant in areas where fresh water is in short supply. The high centrifugal force in a decanter centrifuge drastically increases the dewatering efficiency, as one would expect when comparing static settling at $1 \times g$ with centrifugal separation at up to $3000 \times g$. The continuously discharged solids are dry to the touch and can be easily transported to a dump site to be deposited. The recovered water can be reused in the process plant and will increase the water efficiency. This paper reviews current practices for tailings dewatering and provides examples of the application of decanter centrifuges for the dewatering of diamond and gold tailings for dry stacking.

INTRODUCTION

Mine tailings are the ore waste of mines and are typically a mud-like material. Worldwide, the storage and handling of tailings is a major environmental issue. Many tailings contain toxic substances and must be kept perpetually isolated from the environment. The scale of tailings production is immense, since metal extraction is usually only ounces or pounds for every ton of ore. Tailings containment facilities, such as that illustrated in Figure 1, are regarded as the world's largest man-made objects.

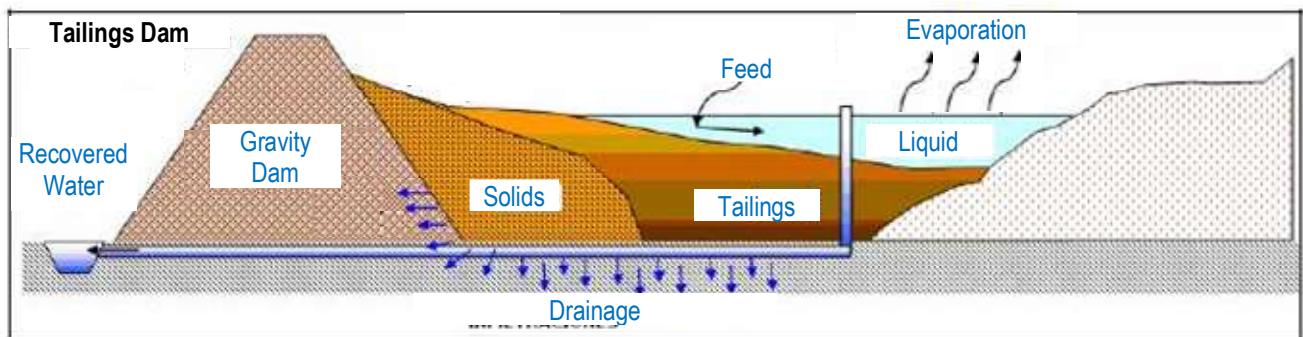


Figure 1. Cut-away wet tailing dam.

(Source: <http://fitv.bligoo.com/content/view/153/Deposito-de-Pasta-la-region-a-la-vanguardia-en-innovacion-en-tratamiento-de-residuos-mineros.html#.WnlM5rnrtAQ>)

In "dry-stack" disposal, tailings are stored in dry form, typically by burial in a covered and lined pit. In this regard, dry-stack storage, as illustrated in Figure 2, is similar to a modern, sealed landfill. This method takes up much less space, is less susceptible to earthquake hazards, and does not require active water treatment. This makes it particularly relevant in locations where water is scarce, earthquake risks are high, or space is limited.

Dry-stack disposal has, however, much higher up-front costs than wet storage. Dry-stack tailings must be dried, and the solid tailings must be transported by truck or conveyor instead of by slurry pipeline, which adds logistical complexity and cost. This method is currently used in operations where conventional tailings deposition is not an option or process water recovery is desirable.

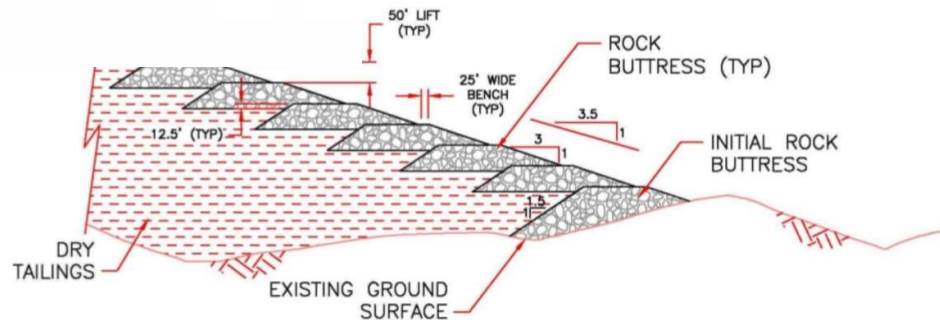


Figure 2. Cut-away dry tailing dam.

(Source: <https://www.slideshare.net/Rosemont-Copper/dry-stack-tailings-overview>)

Enclosures for dry-stack storage, like the dams around artificial lake impoundments, must be maintained in perpetuity. The long-term maintenance requirements are, however, much less than for large, wet tailings impoundment with dams. In some cases, where the material dewateres well, the tailings can be stored in stable deposits requiring no retention bunding, as is the case at La Coipa in Chile, shown in Figure 3.



Figure 3. The "dry stack" tailings facility at La Coipa, Chile.

(Source: [http://www.cbc.ca/kamloops/mt/2014/08/28/dry-tailings-stack-versus-wet-tailings-pond.](http://www.cbc.ca/kamloops/mt/2014/08/28/dry-tailings-stack-versus-wet-tailings-pond/))

DEWATERING OF TAILINGS

The dewatering of tailings for dry-stacking means that tailings do not have to be stored in ponds or sent as slurries into oceans, rivers or streams. There is a growing use of the practice of dewatering tailings using vacuum or pressure filters (Davies & Rice, 2001). This saves water, which potentially reduces the impact on the environment in terms of a reduction in the potential seepage rates and space used, leaving the tailings in a dense and stable form and eliminating the long-term liability that ponds present after mining is finished. While there are potential merits to dry-stacked tailings, these systems are often cost-prohibitive due to increased capital cost to purchase and install the filter systems and the increase in operating costs (generally associated electricity consumption and consumables such as filter cloth) of such systems.

Alternative Technology to Dewater Tailings

In a tailings dam, the solids are settled by sedimentation, so the force on the sediments is the natural earth gravity. There are several technologies available to speed up the dewatering.

High-capacity thickener

Most tailings dewatering processes use a thickener to increase the solids concentration. The sludge is pumped into large settler with conical bottom. Typically, the sludge enters the settler from above, but in the high-capacity thickener the sludge is pump into the solid layer of the settler, where the already existing solids act as a filter medium, so only the process solution passes through the solids and exits the settler, solid-free, via the overflow.

Belt filter press

The flocculant-treated, low concentration sludge is loaded into a hopper and distributed onto a moving, porous belt. The sludge is squeezed through a series of progressively tighter rollers to expel process solution. The thickened sludge "cake" is collected in another hopper, while the water is generally drained.

Chamber filter press

Chamber filter presses are made up of polypropylene squares with a concave depression and a hole at the centre. Two plates join together to form a chamber to pressurize the slurry and squeeze the filtrate out through the filter cloth lining in the chamber.

As the filter cake becomes thicker, the filter resistance increases as well. When the separating chamber is full, the filtration process is stopped as the optimum pressure difference is reached. The filtrate that passes through filter cloth and flows through collection pipes. The plates of the filter press are then pulled apart and the cake that accumulated in the hollow frame falls out, to be discharged to the final collection point. Cake discharge can be done in many ways: for example, by shaking the plates while opening or shaking the cloths. Scrapers can also be used, by moving from one chamber to another and scraping the cake off the cloth. The cloth needs to be cleaned regularly using wash liquid.

While the use of filter presses for tailings dewatering was mentioned as early as 1903, it was only in the 1980s that this was put into large-scale commercial practice. By 2011, filter presses had become more common than thickened tailings operations (Murphy & Caldwell, 2012).

Centrifuges

Mechanical separation technology by centrifuge was developed approximately 100 years ago. This technology allows a continuous processing of sludge. In a centrifuge, the solids are affected by centrifugal force. Centrifugal force is linked to two parameters: distance to the rotating axis and the speed of rotation. Today, centrifugal forces of 3000 times earth gravity (g) are typical for dewatering any kind of sludge.

In a centrifuge, the sludge is continuously pumped through the feed pipe and enters the centrifuge through the feed chamber into the rapidly spinning rotor. Figure 4 shows a sectional view of the inside of a decanter centrifuge.

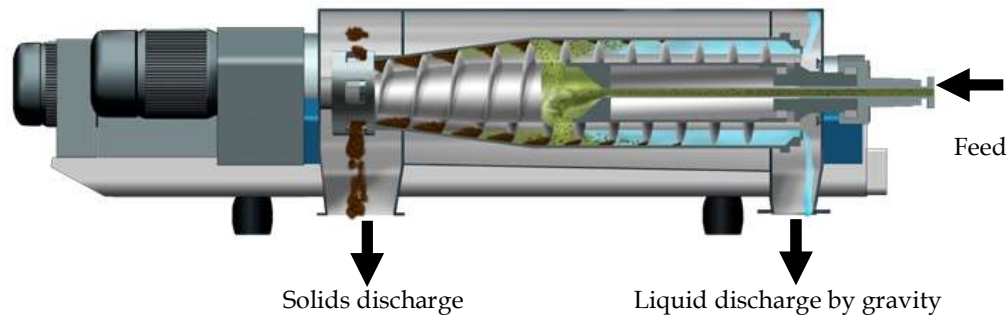


Figure 4. Cut-away of solid bowl decanter centrifuge. (Source: Flottweg SE.)

The centrifugal force causes the sludge to form a ring inside of the rotor. As the density of the solids is higher than that of the liquid, the solids settle on the inside wall of the rotor. To remove the settled solids, a scroll rotates inside the rotor, with a differential speed with respect to the rotor, and conveys the accumulated solids towards the discharge ports.

The bowl is tapered toward the solids discharge ports of the centrifuge so that, at a certain point, the solids will exit the liquid zone and will pass into the dry “beach area”. Here, the solids dewater further until they are discharged through ports via centrifugal force. As the diameter of the solids discharge section is smaller than the diameter of the liquid discharge section, the liquid (centrate) can only exit the rotor on the liquid-discharge side. By adjusting the weir plates, the pond depths and the dry area can be adjusted. The following effects result from the adjustment of the weir plate.

Setting the weir plates to a larger diameter results in:

- decrease of pond depths;
- less retention time for the sludge;
- less time for clarification;
- liquid discharge (centrate) may be contain suspended fines;
- increased drying distance;
- lower moisture content in the solids discharge.

Decreasing the diameter of the weir plates has the opposite effects.

THE EFFECT OF USING CENTRIFUGES

The use of centrifuges for dewatering of tailings has several advantages over other dewatering technologies, such as belt filter presses and chamber filter presses, as illustrated in Table I.

Space / Support Requirements

Figure 5 shows the extent to which the typical space/support requirements for the installation of mechanical separation technologies differ.

Table I. Comparison of several dewatering technologies based on long-term business experience.

	Belt Filter Press	Chamber Filter Press	Decanter Centrifuge
Installation	🌳🌳🌳	🌳🌳🌳🌳🌳	🌳
Space	🏠🏠	🏠🏠🏠	🏠
Maintenance	🔧	🔧🔧🔧🔧	🔧
Ventilation	🌀🌀🌀🌀	🌀🌀	🌀
Water	💧💧💧💧💧💧💧	💧💧💧💧	💧
Air	💨	💨💨	
Labour	👷👷👷	👷👷👷	👷
Power		⚡	⚡

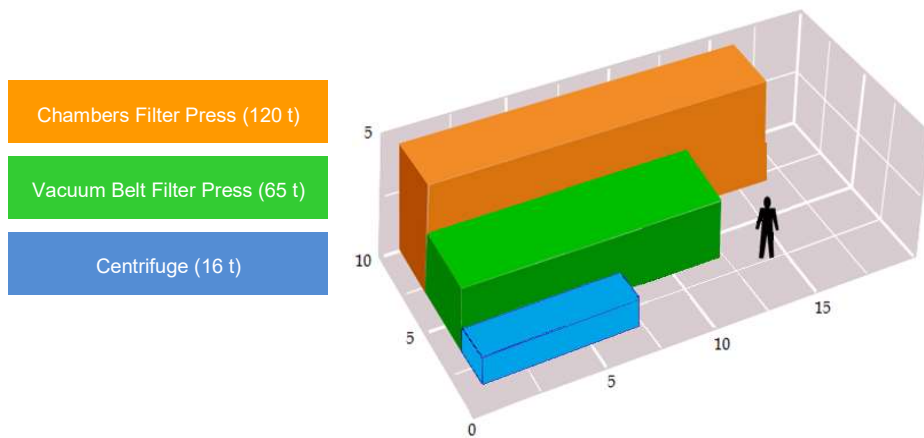


Figure 5. Space requirements (in m) / Support requirements (in t) of separation equipment with a hydraulic capacity of 100 m³/h and solid load of 20 000 kg dry matter/h, based on business experience. (Robert Klug, Flottweg SE.)

Dewatering Results

The dewatering capacity of a centrifuge and a chamber filter press are almost identical, ranging from 65 to 75% dry solids for minerals slurry feed. A belt press would usually achieve slightly lower values. The actual residual moisture achievable for any application is dependent on the particle size distribution of the solids. The finer the particle size range, the more moisture will be entrained. A centrifuge will usually capture all particles above 5 µm in size. The use of a suitable flocculant is necessary to capture the ultra-fine particles, if clean centrate is required. Typically, the solids discharged would have a free flowing, crumbly consistency, and are dry to the touch.

Separation Efficiency

Figures 6 and 7 illustrate the drastic volume reduction of the tailing sludge that is achievable with a centrifuge. One specific advantage a decanter centrifuge has over filters is that there is no filter cloth that can become blinded with fine particles. This means that the flow rate through a centrifuge will remain constant.

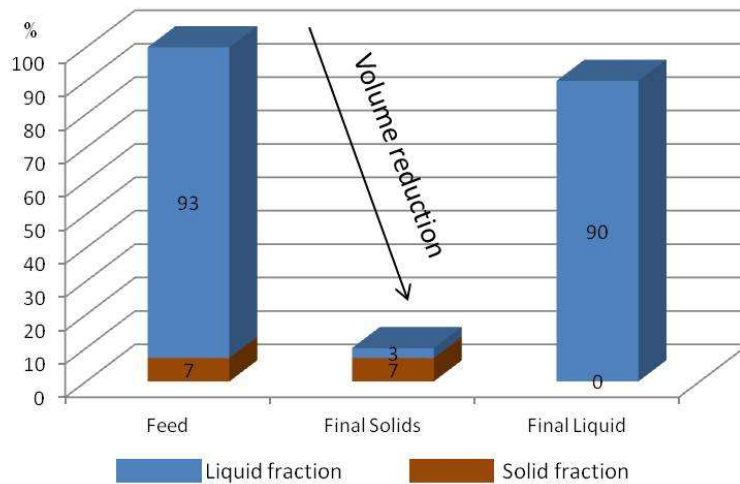


Figure 6. Typical volume reduction of solids containing fraction. (Robert Klug, Flottweg SE.)



Figure 7. Photographs of feed, solid discharge and centrate from centrifuge. (Photographs taken by Robert Klug, Flottweg SE, at Sibelco sand pit mine, Italy.)

APPLICATION EXAMPLES

Case Study - Lipari Braúna Diamond Mine, Brazil

The Braúna Diamond Mine, operated by Lipari, is located in the state of Bahia, about 400 km southwest of Salvador. It is the first diamond mine in South America developed on a kimberlite deposit. The open pit mine feeds 2000 t/d of ore to the processing plant. The mine operates on a 24h/d, 7 d/week basis. The area where it is located is very dry and fresh water is supplied from a nearby river, which runs dry for 3 months/year. The government requires a water recovery of >80% to keep the mine operational.

In 2013, Flottweg lost the contract for the supply of a centrifuge to one of its competitors. The company in question installed a 600 mm machine to handle 10 t dry solids (DS)/h. During commissioning and subsequent operation, it became clear that the centrifuge could not handle the throughput and was very difficult to control. This illustrates the importance of the equipment supplier having a clear understanding of the process and experience in the particular field.

In February 2017, Lipari asked Flottweg to provide a pilot unit to site for further trials. A Z92-4/451 SP4.3 (as shown in Figure 8) was installed and was immediately able to process more than 20 t/h DS. Further optimisation of the operation led to a throughput averaging around 39 t/h DS, recovering a

“solids-free” centrate (as shown in Figure 9). Operating parameters for the centrifuge are as shown in Table II and the particle size distribution in Figure 10.



Figure 8. Centrifuge installation at Lipari's Braúna Diamond Mine.
(Photographs taken at Lipari diamond mine by Robert Klug, Flottweg SE.)



Figure 9. Centrifuge solid and liquid discharge at Lipari's Braúna Diamond Mine.
(Photographs taken at Lipari diamond gold mine by Robert Klug, Flottweg SE.)

Table II. Operating parameters for centrifuge at Lipari's Braúna Diamond Mine.

Feed flowrate	Up to 70 m ³ /h
Solids loading	45%
Solids feed rate	Up to 36.7 t/h
Drum speed	930 rpm
Centrifugal force	445x g
Solids recovery	>99.9%
Dry matter contents in solid discharge	>60–65% w flocculent, 72% w/o flocculent
Operational power consumption	30 kW main drive, 25 kW scroll drive
Flocculant consumption	0.2–0.6 kg/t dry matter
Water Recovery (overall process)	>95%

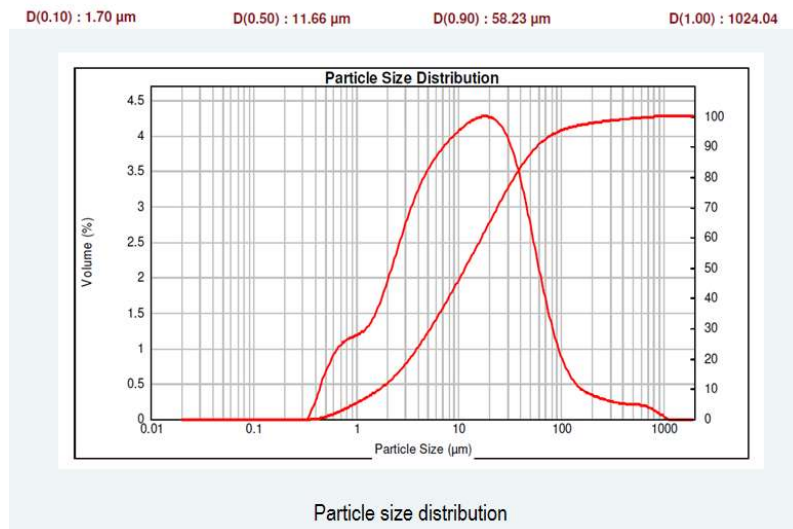


Figure 10. Particle size distribution of tailings at Lipari's Braúna Diamond Mine.

The centrifuge has been operating continuously, for more than 8000 h/year. So far, no deviation on performance or equipment has been detected. It is interesting to note that the tailings are being effectively dewatered using a force of only 440 x g. At this low force the wear on the scroll is minimal.

Case Study - Buenaventura, Peru

Buenaventura's Uchacchacua Mine in Peru is a gold and silver mine about 200 km northeast of Lima, at an altitude of 4400 m above sea level. At present, the tailings are routed to a tailings dam, where the solids settle and the process water flows down the mountain. As this practice is environmentally unacceptable, Uchacchacua was faced with extending the tailings dam at a cost of USD 30 million or dry stack the tailings in another location.

Uchacchacua opted to go the dry stacking route and Flottweg was invited to run pilot trials to assess the feasibility of dewatering the tailings. A Z92-4/459 SP 4.3 was installed and the results satisfied the mining company's engineer. It was specifically noted that the centrate from the centrifuge was clear and could be reused in the process plant.

Operating parameters for the centrifuges are as shown in Table III and the particle size distribution in Figure 11.

The success of the centrifuge at the Uchacchacua mine led the mine managers to request that the centrifuge be immediately moved to the Buenaventura Tambomayo mine, which is located in the area of Arequipa, at an altitude of 4800 m.

Table III. Operating parameters for centrifuge at Buenaventura's Uchacchacua mine.

Feed flowrate	Up to 120 m ³ /h
Solids loading	8–23%
Solids feed rate	Up to 24.7 t/h
Drum speed	1300 rpm
Centrifugal force	860 x g
Solids recovery	>99.9%
Dry matter contents in solid discharge	>72–79%
Operational power consumption	75 kW main drive, 50 kW scroll drive
Flocculant consumption	0.3–0.6 kg/t dry matter

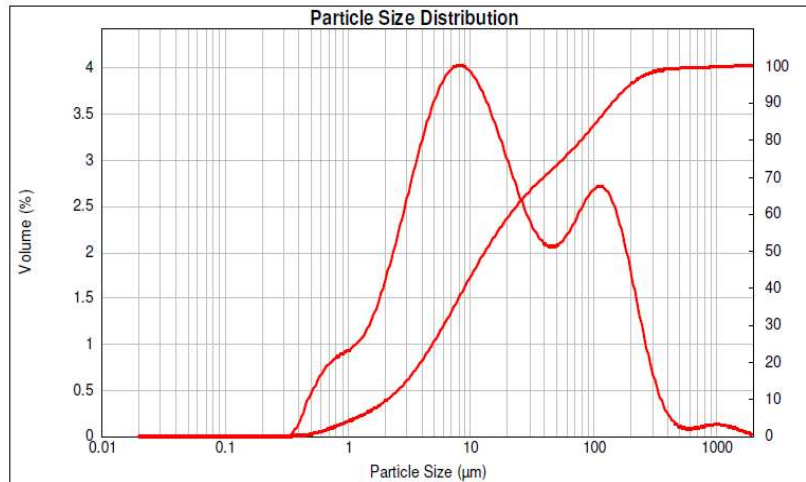


Figure 11. Particle size distribution of tailings at Buenaventura's Uchacchacua mine

The main challenge at Tambomayo was that space is very limited and the environmental agency is strict on water consumption as well on liquid discharge. To meet the environmental regulations, Buenaventura installed two large filter presses to treat 1500 t DS/day, as shown in Figure 12. Each filter press had 91 plates, 3 m x 3 m each. Cycle time was to be 17 min: 5 min loading, 5 min pressing and 7 min discharge. Washing of the cloths was intended to be done once per week, with only one operator required per shift.

After commissioning it was found that the chamber filter presses only reached a capacity of about 20 t DS/h each, which added up to less than 1000 t DS/day. Cycle time was increased to 22 min, washing of the cloth had to be done twice per day and 10 workers were required to discharge the filter cakes in two filter presses. Because the mine did not have a wet tailing dam facility, it had to cut production to be in line with the capacity of the chamber filter presses.



Figure 12. Multi-story filter press building at Buenaventura's Tambomayo mine.

The centrifuge (Figure 13) was moved to the new site, installed and commissioned in a period of three weeks. It was installed on a 2 m high steel structure and the solid discharge was transported by two belt conveyors to a truck loading site (Figure 13). Feed, with a solid contents of about 49% DS, was taken from the nearby thickener. The solid contents in discharge from the centrifuge is 67–70%, with a clear centrate. Nominal capacity is about 600 t/day.



Figure 13. Centrifuge installation at Buenaventura Tambomayo gold mine.
(Photographs taken at Buenaventura Tambomayo gold mine by Robert Klug, Flottweg SE.)

With the installation of the single centrifuge, the mine could return to operating at full capacity. Operating parameters for the centrifuges are as shown in Table IV and the particle size range of the tailings in Figure 14.

Table IV. Operating parameters for centrifuge at Buenaventura's Tambomayo gold mine.

Feed flowrate	Up to 100 m ³ /h
Solids loading	45%
Solids feed rate	Up to 39.5 t/h
Drum speed	925 rpm
Centrifugal force	440 x g
Solids recovery	>99.9%
Dry matter contents in solid discharge	>67–70%
Operational power consumption	35 kW main drive, 30 kW scroll drive
Flocculant consumption	0.05–0.15 kg/t dry matter

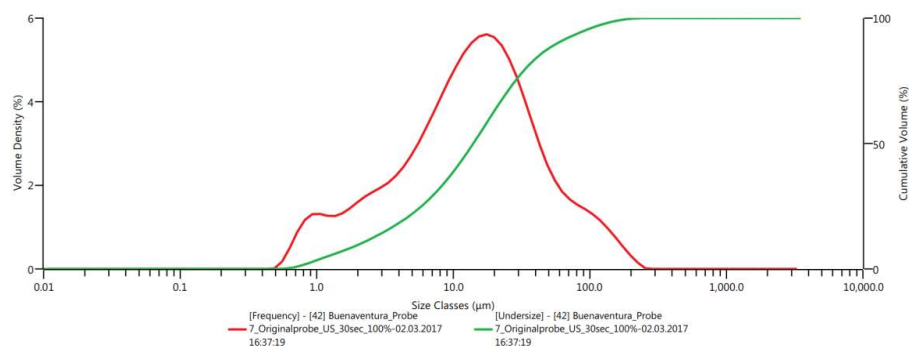


Figure 14. Particle size distribution of tailings at Buenaventura's Tambomayo mine.

The impact of the installation of the centrifuge at Tambomayo has been very significant for Buenaventura. The minimal requirement for civil infrastructure and small footprint made it possible to deploy the centrifuge very rapidly, even though Tambomayo had never planned for a centrifuge installation.

Although Tambomayo was inexperienced in the use of centrifuges, the machine was very easy to run with minimal staff requirements. The normal daily operational throughput exceeded that of one of the existing filter presses, averaging at 600 t/d of DS. At one stage, both filter presses had to be taken off-line for maintenance, and the centrifuge was able to handle the throughput of both filter presses, enabling operations to continue.

Tambomayo is planning to install two centrifuges by 2019 to replace the filter presses. Management is also considering installing a third unit as a standby and to handle the future expansion to 2000 t/d. The pilot installation will remain on site until the new machines are delivered.

Table V shows a comparison of costs, operability and performance of the Tambomayo centrifuge with the filter presses, based on data provided by Buenaventura.

Table V. Comparison between Tambomayo chamber filter press and centrifuge.

Comparison at equal capacity / day		
	Chamber filter press	Centrifuge
Process	Discontinuous	Continuous (24/7)
Filtration area (m ²)	819	–
Filtration volume (m ³)	up to 20	up to 1
Capacity (t DS/h)	up to 100	up to 30
Investment cost	100%	60%
Space	100%	20%
Structural support	100%	20%
Extras (crane, etc.)	100%	20%
Cycle time (min)	17–22	continuous
Operating personal (per 8 h)	4–8	1
Maintenance	Regular maintenance	Regular maintenance
	Washing of filter cloths 1–2 x/day	–
	Change of filter cloths 2–4 x/year	–
Maintenance downtime (days/a)	30	5
Maintenance costs	100%	5%
Instrumentation (Qty)	>50	5
Exposure to workers	Yes	No
Feed pump pressure (bar)	6–15	1–2
Required flocculant	100%	100%
Dewatering results	75 % DS	70 % DS
Compressed air supply	Yes	No
Fresh water supply (day)	100%	0–5%
Required power (kW)	100%	100%
Outdoor installation possible	No	Yes
OPEX (USD/t DS)	4–6	2–4

CONCLUSION

The use of centrifuges, for dewatering tailings for dry stacking deposition, is a viable alternative to existing technologies. Based on space requirement and investment cost and operating costs, the mechanical separation of solids and liquids by centrifugal force will increasingly find its way into modern mining and minerals processing operations.

REFERENCES

- Davies, M.P., Rice, S. (2001). An alternative to conventional tailing management-"dry stack" filtered tailings. *Proceedings of the Eighth International Conference on Tailings and Mine Waste*. Balkema, Fort Collins, Colorado, US. pp. 411-422.
- IDC Technologies. Technical References-Civil Engineering. http://www.idc-online.com/technical_references/pdfs/civil_engineering/Mine_Tailings.pdf [accessed 25 March 2015].
- Murphy, F., Caldwell, J. (2012). Filter-pressed, dry-stack tailings. <http://technology.infomine.com/reviews/FilterPressedTailings> [accessed 5 May 2015].
- Tailings handling and storage techniques. <http://www.tailings.info/index.htm> [accessed 20 March 2015].