Mineral paste production from phosphate rock tailings

Produção de pasta a partir de rejeitos de rochas fosfáticas

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Abstract

The dewatering stage is among the most important industrial unit operations, and is widely adopted in many different industries. Nowadays, mineral processing tailings disposal is a big problem due to the environmental degradation it causes. The phosphate rock processing in Anglo American Phosphate Brazil, situated in Catalão/Go/Brazil, generates around 180 t/h of tailings for a plant feed of 480 t/h (approximately 37.5% of the processing plant feed), with 5 to 10% of solids and approximately 14% of P_2O_5. Nowadays, the tailings are sent directly to the tailings dam. The present work proposes paste production using the tailings from the phosphate rock processing plant. Through decantation of a tailings sample, a clarified liquid was obtained and drained. The decanted pulp then went through a second stage consisting of vacuum filtration. Flocculant addition in this stage generated a faster sedimentation rate and a higher dewatering performance in next stage of dewatering, because the flocculated material was retained by the filter medium instead of passing through it. The results were satisfactory for paste tailings production with a solid percentage of around 65%.

keywords: phosphate rock tailings; paste; dewatering.

Resumo

O desaguamento é uma das operações unitárias industriais mais importantes e é amplamente adotada em diferentes indústrias. Atualmente, a disposição dos rejeitos do processamento mineral é um grande problema, devido ao impacto ambiental gerado. O processamento da rocha fosfática na Anglo American Fosfato Brasil, situada em Catalão/GO, gera, aproximadamente, 180 t/h de rejeitos de 480 t/h alimentadas na usina (aproximadamente 37,5% da alimentação da usina), com 5 a 10% de sólidos e, aproximadamente, 14% de P_2O_5. Atualmente os rejeitos são encaminhados diretamente para a barragem de rejeitos. O presente trabalho propõe a geração de pasta produzida a partir do rejeito gerado na usina. O líquido clarificado, obtido através de ensaios de sedimentação, foi drenado e a polpa remanescente foi encaminhada para o segundo estágio, consistindo de filtragem a vácuo. A adição de floculante permitiu uma taxa de sedimentação mais rápida e uma performance mais alta no estágio de desaguamento, sendo o último devido ao fato de o material floculado ter sido retido pelo meio filtrante e não passar pelo mesmo, fato que ocorria sem a adição do floculante. Os resultados obtidos foram satisfatórios para a produção de pasta usando rejeito com, aproximadamente, 65% de porcentagem de sólidos

Palavras-chave: *rejeito de rocha fosfática; pasta; desaguamento.*

1. Introduction

Tailings produced by mineral processing create a large range of environmental issues regarding its disposal, usually in dams, which demand very wide areas, contaminate hydric resources, generate high construction costs and require a long-term monitoring according to environmental regulations. All considering, studies about tailings disposal as paste are ongoing in several countries, since this disposal option usually offers high water recovery and recirculation, low investment and operational costs and low environmental impact.

Usually ores require water for their processing, being mandatory the recovery of most of the water added during industrial processing. The solid/liquid separation process is, therefore, a very important process in the mineral processing chain. These processes have been studied not only because water recovery is obligatory, and resources are scarcer and costlier every day, but also because they consume a great amount of energy (AMARANTE, 2001).

In the specific case of mineral particles smaller than 10 μm, the solid/liquid separation process is extremely affected by the particle dispersion effect, caused by the Brownian motion, characteristic in colloidal systems, making settling difficult. In this case, agglomeration of the solid particles before the solid/liquid separation process must be considered, either by flocculation or by coagulation. The presence of ultra-fine particles in the suspension affect the thickener efficiency, lower the filtration rates and may produce cakes with moisture levels higher than desired. Therefore, the pre-processing of the mineral pulps is important.

According to Hogg (1999), flocculation is a fine-particle agglomerating process in which the particles are aggregated into flocks. The process involves three major steps:

1. **Fine particles destabilization** through the elimination of any particle/particle repulsion force, due to superficial electrical charges or any force which may oppose to agglomeration of the particles;
2. **Flock formation and growth**, when the particle-particle agglomerate develops either by collisions or by adherence;
3. **Flock degradation**, which involves broken mechanisms due to shear stress, turbulence etc. in the flow stream.

Oliveira *et al.* (2004) define filtration as a solid-liquid separation process wherein the mineral pulp is forced to pass through a porous medium (called filter medium) which retains most of the solids and allows liquid phase passage. In the mineral industry, this process is often used after thickening. The correct choice of filter medium is one of the most important aspects for achieving highly efficient filtration, since its function is also to act as a support base for the produced cake. A very important feature required of the filter medium is its capacity of retain solids without obstructing its pores, otherwise liquid passage becomes very difficult, besides being mechanically and corrosion resistant. Usually a blow of air in the cake discharge performs the filter medium clearing.

According to Wills and Napier-Munn (2006), filter medium is manufactured from cotton, wool, linen, jute, nylon, silk, glass fibre, porous carbon, metals, rayon and other synthetics, and miscellaneous materials such as porous rubber. Cotton fabrics are by far the most common type of medium, primarily because of their low initial cost and availability in a wide variety of weaves. They can be used to filter solids as fine as 10μm. However, new materials have emerged as a substitute to the materials usually used. It is possible to highlight the geotextile fabrics.

Lima (2003) defines geotextile fabrics as permeable, flexible and thin fabrics made of synthetic or natural fibres. The geotextile fabrics present advantages in relation to the conventional filter medium, since they are thinner for the same permeability, present easy installation and maintenance, are low cost, and as they are an industrial product, their characteristics can be defined and controlled both physically and chemically. The geotextile fabrics can have their pores obstructed by fine particles in suspension (diameters from 7 to 50μm) during the mechanical filtration. Colloidal particles can be captured by its pores through physical, chemical or electrostatic interactions. In unfavourable conditions for chemical or electrostatic interactions, the colloidal behavior can be different from the bigger particles, by not being filtered and following the liquid flow.

According to Osório *et al.* (2008) a paste tailings can be defined as a colloidal system which presents itself as a homogeneous fluid, in which granulometric segregation of the particles does not occur and does not show significant liquid bleeding when gently disposed in a stable surface. Theriault et al. (2001) propose a simple and practical definition of paste tailings. According to them, paste tailings are tailings that have been sufficiently dewatered so that they do not have a critical flow velocity when pumped, do not segregate when deposited, and produce minimal water bleeding when discharged from the end of a pipe. The increased viscosity associated with this dewatering also means that paste tailings require positive displacement pumps for pipeline transport, thereby limiting the distance over which paste tailings can be economically transported. Typically, paste tailings will flow with a slope of about 3 to 10 degrees, provided the underlying material has stabilized. The construction of stack disposal with paste tailings is a natural follow up from depositing tailings as dense, non-segregating slurry.

The present paper proposes a solid-liquid combination of tests to optimize water from mineral process recovery contained in the tailings generated in the phosphate rock mineral processing by Anglo American Phosphate Brazil. The solid percentage and pH used in the samples were identical to the ones used in the industry. Although nowadays the phosphate rock tailings are sent directly to the tailings dam, a future alternative could be paste tailings production, due to the consistent and satisfactory results presented herein.

2. Material and methods

The phosphate rock tailings used were donated by Anglo American Phosphate Brazil, located in Catalão, Goiás, Brazil. The tested tailings came from the slime produced in a comminution closed circuit and removed by de-sliming cyclones. Nowadays the slime is pumped directly into the tailings dam.

Free settling tests in graduated cylinders of 2.0L were carried out to determine the best flocculant to be used with phosphate rock tailings. The samples were collected directly in the mineral processing plant and delivered to the laboratory in 200L barrels. The barrels were sealed to avoid any water loss or contamination. The tailings in the barrel were homogenised and samples of 10L were collected to feed the free settling tests. The flocculant chosen for the vacuum filtration tests was Kemira Superfloc A-100 (20 mL/L), because it has an excellent performance in the settling tests and was able to produce stable flock for the filtration.

The pH control was performed by a Gehaka T-1000 pH meter and all tests were conducted at pH 7. After flocculant addiction, the samples were left to settle freely for one hour. The clarified liquid produced was drained and its turbidity was measured using a Hanna Instruments model HI 93703C portable turbidimeter. The settled solids were vacuum filtered using a Prismatec 132 vacuum pump for six minutes with an initial vacuum of 93.33kPa. To hold the filter medium, a device made of polyurethane was developed, with an internal diameter of 13cm. The filtered liquid was stored in a Kitasato flask directly connected with the vacuum pump.

Nine different filter medium (regarding composition, finishing and permeability) were tested (three tests for each filter medium and flocculant for a total of 270 tests). Three of the filters were made of Nylon, four from Polypropylene (all made by Remae) and one from a geotextile fabric (trade name Bidim CC-10 made by Bidim). Table 1 shows the major characteristics of the filter medium tested, as well as a picture (9 x 9mm) of each one.

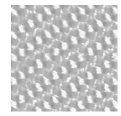
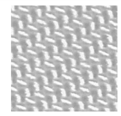
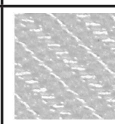
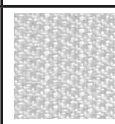
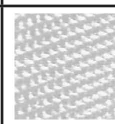
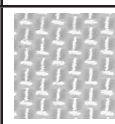
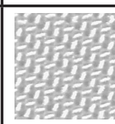
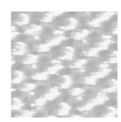
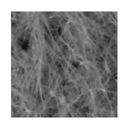
Manufacturer	Trade name	Fiber	Finishing	Permeability [$m^3/s.m^2$]	Picture [9 x 9 mm]
Remae	1097-EL	Multiple wire Nylon	None	0.1167 – 0.2333	
Remae	1097-TE	Multiple wire Nylon	None	0.0250 – 0.1000	
Remae	1142-T	Multiple wire Nylon	Thermoset	0.1667 – 0.2667	
Remae	4230-T	Single wire Polypropylene	Thermoset	1.0000 – 1.3333	
Remae	4233-TC	Single wire Polypropylene	Calendered	0.2500 – 0.3333	
Remae	4400-T	Multiple wire Polypropylene	Thermoset	0.0100 – 0.0200	
Remae	4520-T	Multiple wire Polypropylene	Thermoset	0.0250 – 0.0833	
Remae	4710-T	Multiple sliced wire Polypropylene	Thermoset	0.0050 – 0.0083	
Bidim geo.	CC-10	Geotextile non-tissue 100% polyester	None	0.0700 – 0.1200	

Table 1
Filter medium used in the tests

After vacuum filtering, the paste was weighed and oven dried at 120°C for five hours. The dried paste and the filter medium were both weighed after drying to evaluate the solids percentage in paste tailings produced.

3. Results and discussions

The chemical analysis of the phosphate rock tailings sample used in this work, obtained by X-Ray diffraction, is presented in Table 2 and the granulometric analysis is given in Table 3. For the granulometric analysis, wet screening was performed, which according to Wills and Napier-Munn (2006) permits finer sizes to be processed efficiently, down to 250µm and finer. Both analyses were performed at the Anglo American Phosphate Brazil mineral characterization lab.

Oxide	P_2O_5	Fe_2O_3	SiO_2	BaO	Al_2O_3	CaO	MgO	Nb_2O_5
%	11.10	31.37	21.45	1.22	3.72	12.91	1.62	0.70

Table 2
Analysis of phosphate rock tailings given in terms of oxides

Aperture	μmw	212	149	106	74	53	44	37
	#	65	100	150	200	270	325	400
% accumulated passing	99.32	98.81	98.45	97.59	97.05	96.61	96.16	

Table 3
Phosphate rock tailings granulometric analysis

Figure 1 shows a graduated cylinder of 2.0L used in the free settling tests with phosphate rock tailings flocculated with Kemira Superfloc A-100 (20 mL/L). It is possible to notice the flocks in the graduated cylinder base.

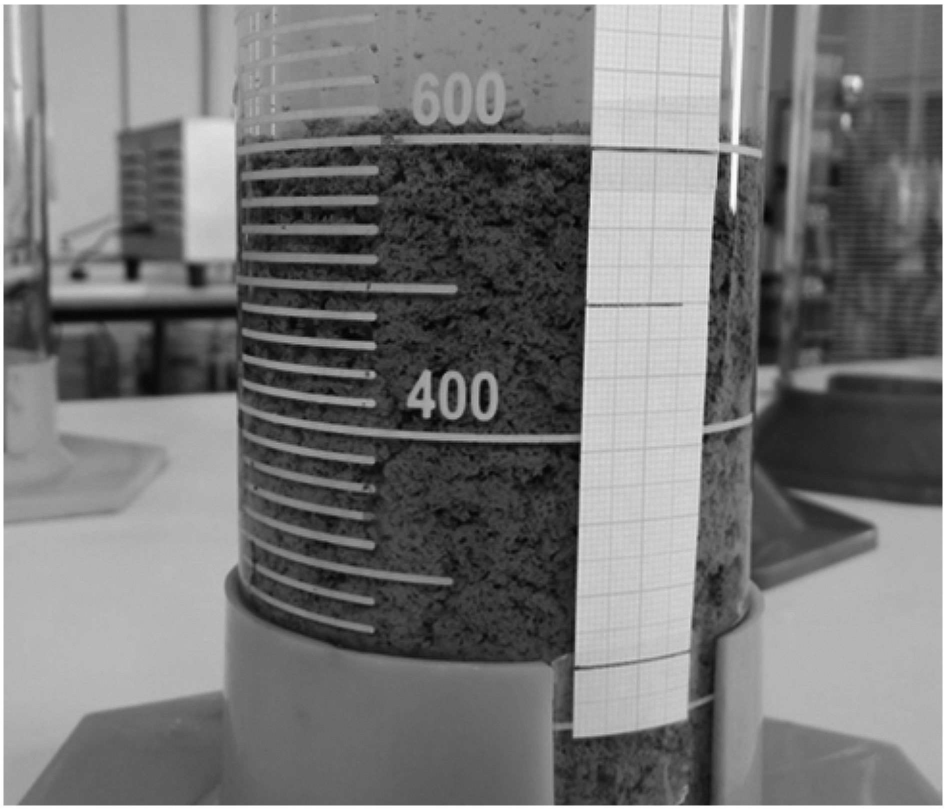


Figure 1
Phosphate rock tailings flocculated with Kemira Superfloc A-100 (20 mL/L)

Figure 2 shows six different paste tailings produced from phosphate rock tailings using the proposed methodology. It is possible to see the reflection of the remaining water present in the paste, although it partially resists shear stress and retains a cylindrical form because of the recipient used in the vacuum filtration, indicating a rheology consistent with paste tailings.

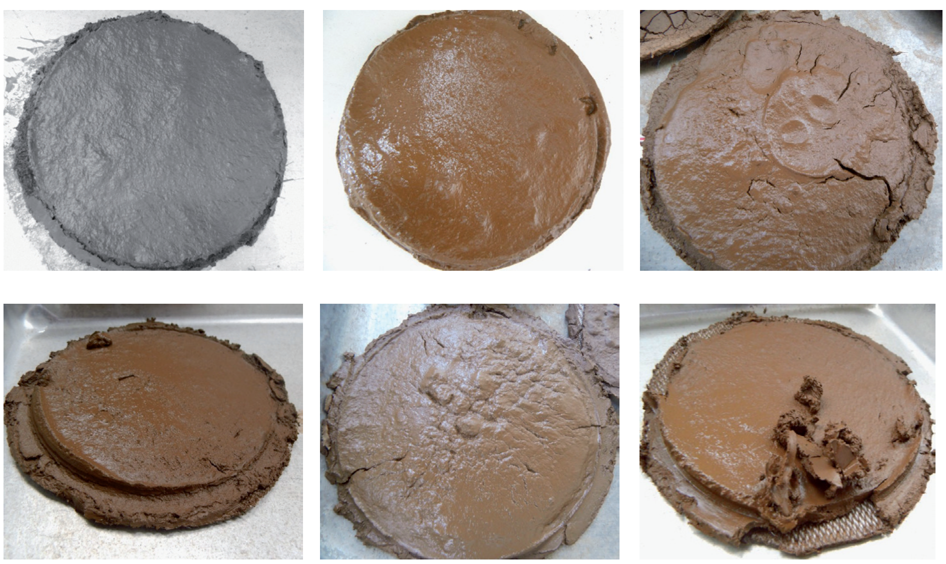


Figure 2
Six different paste tailings produced from phosphate rock tailings

Table 4 summarizes the results of the vacuum filtration tests showing the volume of liquid filtrated, mass and solids percentage in the paste and the pressure drop from the beginning to the end of the test. A high vacuum pressure indicates high permeability from both filter medium and pulp, while a low vacuum pressure indicates low permeability. Notice that for best results (filter medium Remae 4230-T and 4233-TC) according to the solid percentage in the paste, the pressure drop was zero, although both initial and final vacuum pressures were low. This is consistent with the presence of capillary ducts in the paste, which allow the water flow but not spontaneously. For the other filter medium, pore obstruction was noticed after the test and the filter medium needed to be cleaned to remove the remaining particles, which explains the pressure drop. For these cases, the paste height was higher and the solids percentage lower.

Table 4
Average vacuum filtration results for phosphate rock tailings paste tailings production

Filter medium	Flocculated (mL)	Filtrated (mL)	Paste mass (g)	Paste solids percentage (%)	Vacuum (kPa)	
					Initial	Final
1097-EL	615.00	440.00	112.49	59.53	66.66	46.66
1097-TE	190.71	128.57	81.90	54.59	53.33	40.38
1142-T	161.67	96.67	83.17	52.32	52.00	42.22
4230-T	175.00	91.67	81.56	62.42	13.33	13.33
4233-TC	175.00	93.33	79.95	64.55	13.78	13.78
4400-T	175.00	115.00	71.75	47.56	57.77	43.11
4520-T	166.67	95.00	66.16	50.50	34.22	23.11
4710-T	189.29	117.86	94.32	56.10	18.67	16.00
Bidim geotextile	190.00	112.14	96.68	47.81	28.19	19.62

Figure 3 shows the average solids percentage for the filter medium tested with Kemira Superfloc A-100 (20 mL/L). According to the solids percentage, the best result was obtained with Remae 4233-TC (64.55 %).

The geotextile fabric presented a poor result (47.81 %) and often showed tailings remaining in it after the test and its cleaning was very difficult, due its own nature and fabric.

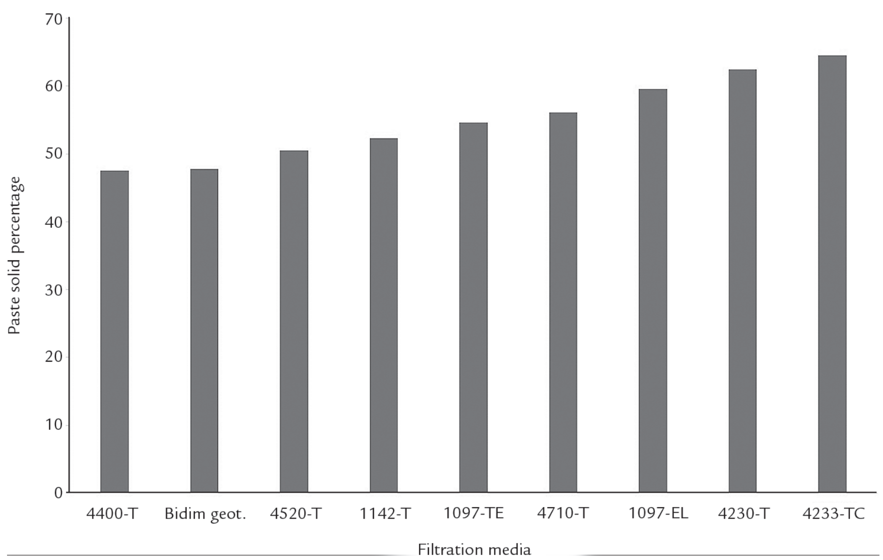


Figure 3
Average solids percentage in the produced paste tailings

It was not possible to establish a statistical correlation between the pressure drop and the solids percentage (see Figure 4), in great part because of the differences in filter medium permeability. There was no pressure drop for the two best filter mediums (Remae 4233-TC and Remae 4230-T), both with high permeability values (60.0 – 80.0 and 15.0 – 20.0 m3/min/m2, respectively). However, both the Remae 4710-T (with low permeability, 0.3 – 0.5 $m^3/min/m^2$) and the geotextile fabric (medium permeability, 4.2 – 7.2 $m^3/min/m^2$) had small pressure drops but with different values of solids percentage in the paste produced (56.10 and 47.81, respectively).

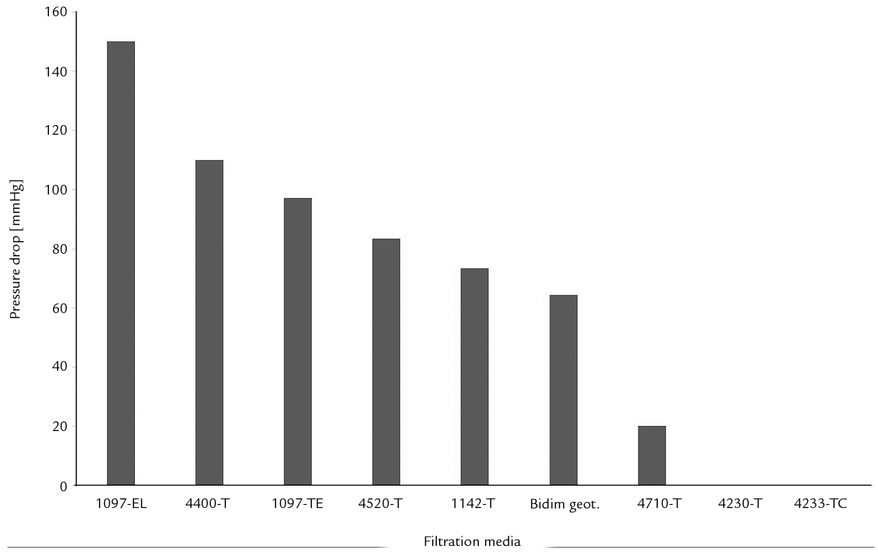


Figure 4
Average pressure
drop in the vacuum filtration tests

4. Conclusions

Remae 4233-TC and 4230-T showed higher efficiency for solids retention in vacuum filtration tests. For these filter medium, no pressure drop was noticed, which indicates lower pore obstruction.

Visual and tact analysis of the produced cake indicated behavior compatible with paste tailings and the adoption of this strategy can lead to a considerable economy with tailings disposal, replacing the actual system using a tailings dam by a pile disposal system. More tests are still ongoing aiming in determine the optimal pH for free settling and to characterize the rheology of the paste tailings produced.

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