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Zinc Concentrate Dewatering Pressure Filtration

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Abstract: Zinc concentrate dewatering is crucial in zinc production, as it allows for the efficient removal of water content from the concentrate before metallurgical processing. It's important for each mining companies to tailor their dewatering processes to the specific requirements of their ore and production facilities. Erma Reka Concentrator processes lead-zinc ores by flotation and produces lead and zinc concentrates. After thickening and filtration the zinc concentrate moisture is 10.5%. This study aims to answer the following research question: how to reduce the moisture content of zinc concentrate to 7%? Dewatering experiments with a laboratory vertical plate airblow (VPA filter) have been conducted in the Process Equipment Test Center of Metso Sweden in Sala, with zinc concentrate sample from Erma Reka Concentrator, (Gorubso Zlatograd), Bulgaria. The aim of the laboratory test work was to evaluate the possibility of zinc concentrate dewatering and to collect data for equipment sizing of VPA filter for 6 metric tph dry solids achieving 7 % w/w filter cake rest moisture. It was found that the zinc concentrate dewatered well and is suitable for VPA filtration. This research offers significant insight to possibilities for zinc concentrate dewatering by pressure filtration. Finally, conclusions and summaries are presented.

Keywords: Pressure filtration, Zinc concentrate, Dewatering

Introduction

As stated by Tomova (2023) mineral processing is mainly focused on extracting the most valuable components from the ore, while the rest of the material is disposed at the tailing ponds. The major operation for removal of solids from a processing solution is solid-liquid separation (Asmatulu, 2011), (Sutherland, 2007). These separation techniques are diverse and mainly include vacuum, pressure and centrifugal filters, screens, trommels, hydrocyclones, thickeners, classifiers, and reverse osmosis (Tarleton & Wakeman, 2007).

As well known the dewatering concentrates by pressure filtration is a common process in the mineral processing industry. This process aims to reduce the moisture content in the concentrate, making it more suitable for transportation and further processing. The choice of dewatering method depends on various factors, including the specific characteristics of the concentrate, required moisture levels, and the available equipment and resources. It's essential to consider the efficiency, operating costs, and maintenance requirements of each method to determine the most suitable approach for application.

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Pepper et al. (2010) defined the reasons, for pressure filters application: (1) to reduce the cost of concentrate transporting from the concentrator to the smelter; (2) to prevent segregation of concentrate solids in sampling on road dispatch and at the receiving smelter, which can affect metal accounting; (3) to reduce the cost of concentrate drying prior to smelting (Pepper et al., 2010).

According to Asmatulu (Asmatulu, 2011) filtration is an unavoidable step in beneficiation plants after the valuable particles are thickened. Usually the fine dewatered sulfide minerals moisture content is between 10% and 20%, depending on the applied dewatering methods and particle size (Rushton at al., 2000), (Asmatulu, 2001). In recent years, with introduction of new technologies in metallurgy, the requirements for zinc concentrate qualities have increased and for shipping the zinc concentretes into the smelting process, the moisture have to be 5–8% (Asmatulu, 2011).

It was reported in literature that twenty years ago, automatic pressure filters were a novelty in the minerals and metallurgical industries and many plants used a combination of vacuum filters and thermal dryers (Townsend, 2003). Currently, almost every beneficiation plant have installed pressure filters to concentrates dewater (Townsend, 2003). Many existing plants as Erma Reka Concentrator have replaced or are replacing their vacuum filters by pressure filters.

Townsend (2003) studied the reasons for widely used of automatic pressure filters in the minerals and metallurgical industries during the last years. Benitta et al., (2021) traces the advances in mineral processing dewatering and drying. The authors draw our attention to technologies in mineral dewatering and drying developed over the last decade. In addition gives a brief discussion of future investigation needs and potentialities from the industrial perspective (Benitta et al., 2021).

Lead and zinc are some of the most common non-ferrous metals worldwide. These are metals mined from both sulphide and oxide lead-zinc ores or lead-zinc-copper-pyrite ores. The main minerals in these ores being galena and sphalerite. Erma Reka Concentrator (Gorubso Zlatograd, Bulgaria), is situated in the south central part of the Republic of Bulgaria, in immediate proximity to the Bulgarian-Greek border. The factory processes lead-zinc ores from the Ermorechensko - Madansko ore field, from three deposits: "Marzyan-North’", "Yuzna Petrovitsa" and "Shumacheski Dol-Androu". An annual Erma Reka Concentrator production of lead and zinc concentrates was achieved in the amount of 19 200 tons per year. The processing of lead-zinc ores is carried out in the flotation divisions. During the lead-zinc ore filtration processing lead and zinc concentrates and final waste are obtained. Concentrates dewatering is performed in two stages: thickening and filtration. After dewatering, the zinc concentrate moisture is 10.5%. The metallurgical industry requires the zinc concentrate moisture to be below 9%. To overcome this problem, in the next sections we demonstrate the laboratory tests to zinc concentrate moisture reduce. Furthermore, investigations on zinc concentrate physical properties and particle size distribution of the sample were carried out.

In the course of our experiments Metso laboratory vertical plate airblow played an important role. Dewatering concentrates by a VPA (Vertical Plate Airblow) filter is a specific type of pressure filtration method that offers distinct advantages in certain applications. It utilizes a series of vertically arranged plates that exert pressure on the slurry to separate liquid from solids. VPA filter was chosen for dewatering zink concentrate for the following reasons: high dewatering (filtration) efficiency, optimized pressure control, high solids recovery, continuous operation, compact design (suitable for installations with space constraints), low operating costs (such as low energy consumption and efficient cake washing), automated control (equipped with automatic controls and monitoring systems to optimize the filtration process and ensure efficient operation), suitable for small-scale mineral processing plant such as Erma reka Concentrator.

Materials and Methods

Test equipment and procedures used are described in this section. Furthermore, investigated process parameters are discussed.

Zinc Concentrate Physical Properties Determination Study

Acording to Wakeman (Wakeman, 2007), if the particle properties could be specified for a filtration, the target properties would be for the particles to have as large size as possible, be as near to spherical as possible, and have a monosize distribution. In practice, is rarely the mean size in a distribution and even small increases in the number of the finer particles can significantly reduce filtration rates (Wakeman, 2007). Particle shape primarily affects the volume and surface area of the particles, and hence their specific surface and the rate of fluid flow through formed filter cakes (Wakeman, 2007).

Fränkle at al. (2022), highlight that particle properties have a profound effect on the specific resistance of the filter cake that in turn affects filter performance. They concluded that the most important properties of the particles are their size, size distribution, shape, and their interaction with the surrounding fluid (Fränkle at al., 2022). Particle size has a significant effect on the solid/liquid separation behaviour of a suspension; knowledge of the techniques for measuring the size particles is therefore important (Wakeman, 2007). The solids composition affects filtration rate through density, surface charges and compressibility. One slurry sample of 35 kg zinc concentrate was tested in the Equipment Test Center of Metso Sweden AB in Sala, Sweden. A representative sample was gathered from the sample, the gathered sample was then used for particle size distribution and specific density measurement. The particle size distribution for the material can be seen in Figure 1.

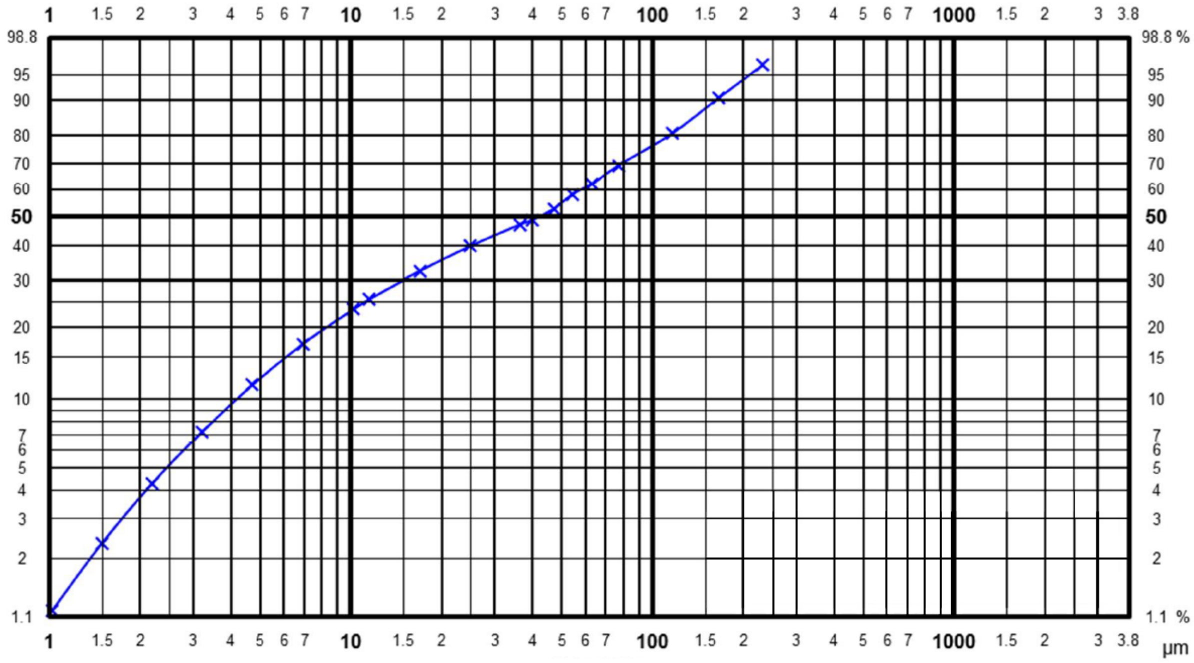

Figure 1. Particle size distribution of the sample

Figure 1 shows the combined particle size distribution curves, where the laser diffraction curve has been adjusted to the mechanical screen analysis. According to Haramkar at al. (2021) for particle size analysis various methods are available depending on the samples type and nature: the most commonly used technique - laser diffraction, one of the oldest and widely used techniques - sieving. The particle size distribution of the sample in our study was determined by mechanical screening (Retsch AS200) down to 40 µm and with laser diffraction (Malvern Mastersizer 3000E) of the particles passing 63 µm. The specific density of the solids was determined with a gas pycnometer (AccuPyc 1330 Pycnometer).

As a result of lower-quality and complex ores increasingly mining, their processing requires finer grinding in order to liberation of the valuable minerals. This also results in finer flotation concentrates production. Haramkar at al. (2021) emphasize that to describe the particle size distribution, D-values are commonly used. With respect to the average particle size, Townsend (2003) reported that flotation concentrates with a D80 >74 µm were once the norm, whereas in the early 21st century the D80 is more likely to be between 20 and 45 µm.

Our results indicate the particles in the studied sample have the following composition: 80% of the particles are smaller than 113 µm (D80), 50% of the sample contains particles smaller than 42 µm (D50) and particles below 10 µm are 23%. Wakeman (2007) explained that the most important for characterising a particle size for filtration rarely is the mean size (50% size) in a distribution; the finer particles in the distribution usually “control” the filtration and it is preferable to compare the 5 or 10% sizes (Wakeman, 2007).

It should be noted that sample presented contains larger particles and sludge resistance should decrease. Less differential pressure should be necessary to achieve target filtration rates and cake moistures. D80, D50 and D23 for the curve can be seen together with some other basic physical properties of the sample in Table 1. In our opinion, understanding the particle properties allows scientists and engineers to tailor filtration systems to specific applications. The selection of appropriate filter media and operational parameters depends on a thorough understanding of the characteristics of the particles to be filtered.

Table 1. Physical properties of the sample

Sample Marked		
Solid content (% w/w)		53.7
Solid specific density (g/cm^3)		3.97
pH		6.0
Particle size		
	-D_{80} (μm)	113
	-D_{50} (μm)	42
	-D_{23} (μm)	10

The solids concentration of the sample was 54 % by weight. Since the solids concentration stated from the Erma Reka concentrator was 50 %, the sample was diluted with tap water to 50 %, and this diluted sample was used for the test work.

Procedure

The tests presented in this paper used a laboratory VPA Pressure Filter provided by Metso (Figure 2).

Figure 2. Laboratory VPA pressure filter

The Laboratory VPA Filter simulates the major operating steps of a full size filter:

- Filtration
- Membrane compression
- Air blow

It comprises a single filtration chamber over which the filter cloth is placed, to provide double sided filtration. The filter head is fitted with a rubber membrane or diaphragm that is activated by compressed air before and during air blow. The feed slurry is held in a small tank and is re-circulated by a variable speed positive displacement hose pump to prevent the solids settling in the tank. During filtration the tank is pressurised with air to provide the filtering pressure.

Individual regulators are used to control the filtration pressure, the membrane compression air pressure and the cake air blow pressure. A scale with a digital readout is used to measure the filtrate discharge. All pressures (feeding, membrane and air blow), slurry temperature and filtrate weight are automatically logged during the whole filtration cycle.

The vertical filter chamber of the laboratory pressure filter type VPA has shown on the Figure 3.

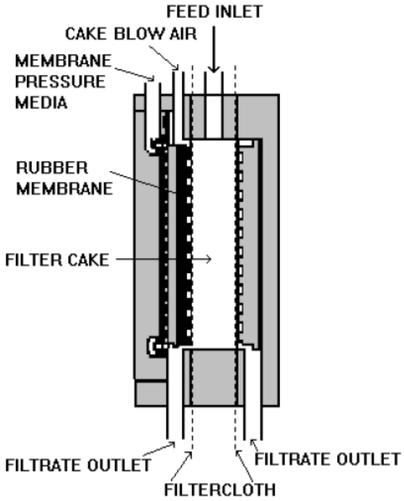

Figure 3. Filter chamber

The laboratory pressure filter type VPA has one vertical filter chamber (Figure 3). The filter simulates the major operating steps of a full size filter: filtration (feeding), membrane compression (squeezing) and air blow (drying). The filter is not opened between the different steps (the pressure across the cake is at no time released during the cycle).

The filtration (cake build up) is two sided in the VPA filter with filtrate outlets at both sides of the cake. The filtration step is typically continued until the filtrate stops, at this point the filtration cannot facilitate further dewatering. At this point the membrane compression step is initiated. The membrane compression step is typically 30 seconds long. Compressed air is used as membrane pressure media. After 30 seconds of membrane compression step the air blow step is applied, the air blow step is typically applied for 6 minutes. During the air blow step compressed air is blown through the filter cake.

The inlet for drying air is placed between the rubber membrane and filter cloth. The filtrate outlet at the membrane side is closed during air through blow step. The membrane is kept activated during the cake air blow, in order to compensate for cake shrinkage that occurs during the dewatering phase. This avoids air leakage through cracks normally formed when the cake shrinks. The filtration area of the chamber is 2 x 1 dm^2. The air through blow area is 1 dm^2. Different chamber depths are available (33, 42 and 53 mm) and different types of filter cloths can be used for testing.

Results and Discussion

The slurry was fed to the VPA at 50 % solids by weight. Four tests were conducted using both 30 and 40 mm chamber thickness. One test was conducted without air blow, using the 40 mm chamber. In all other tests, 6 minutes of air blow was applied. Using the 30 mm chamber, one test was also conducted at increased pressures for membrane compression and air through blow pressure.

The solid/liquid separation is performed by the filter cloth (filtration media). Filter cloth is a crucial component in solid/liquid separation by filtration, and its properties play a significant role in determining the efficiency of the separation process. The key properties that are typically considered for filter cloth include: material composition, weave pattern, thread count, weight, thickness, chemical, abrasion and temperature resistance etc. A multifilament filter cloth S2121-L2K2 from Valmet Fabrics was used in the tests, the filter cloth properties can be seen in Table 2. The test parameters are shown in Table 3.

Table 2. Filter cloth properties

Cloth designation	Type	Material	Weight, g/m^2	Permeability, m^3/m^2/min 200 Pa	Finish
S2121-L2K2	Multi	polypropylene	750	0.8	Calendared

Rezaei et al. (2021) highlight that filtration media has a direct impact on operating costs. The filter cloth selection is based on the characteristics of fluid flow from the cloth pores (Rezaei et al., 2021).

Table 3. Test parameters VPA

Test №	Test 1	Test 2	Test 3	Test 4
Solids content (% w/w)	50	50	50	50
Chamber depth (mm)	42	42	33	33
Temperature (^{0}C)	20	20	30	30
Filtration pressure (bar)	6	6	6	6
Compression pressure (bar)	8	8	8	10
Air blow pressure (bar)	-	7	7	9

Cycle Overview

The filtration, pump feeding, was 3 minutes for the 42 mm chamber (tests 1-2) and 2.5 minutes for the 33 mm chamber (tests 3-4) minutes (Table 3). The compression, squeezing the cake by membrane pressure is initialized after feeding and is applied for 0.5 minutes before the 6 minutes of air blow is applied. The filtrate curve for the entire dewatering tests can be seen in Figure 4.

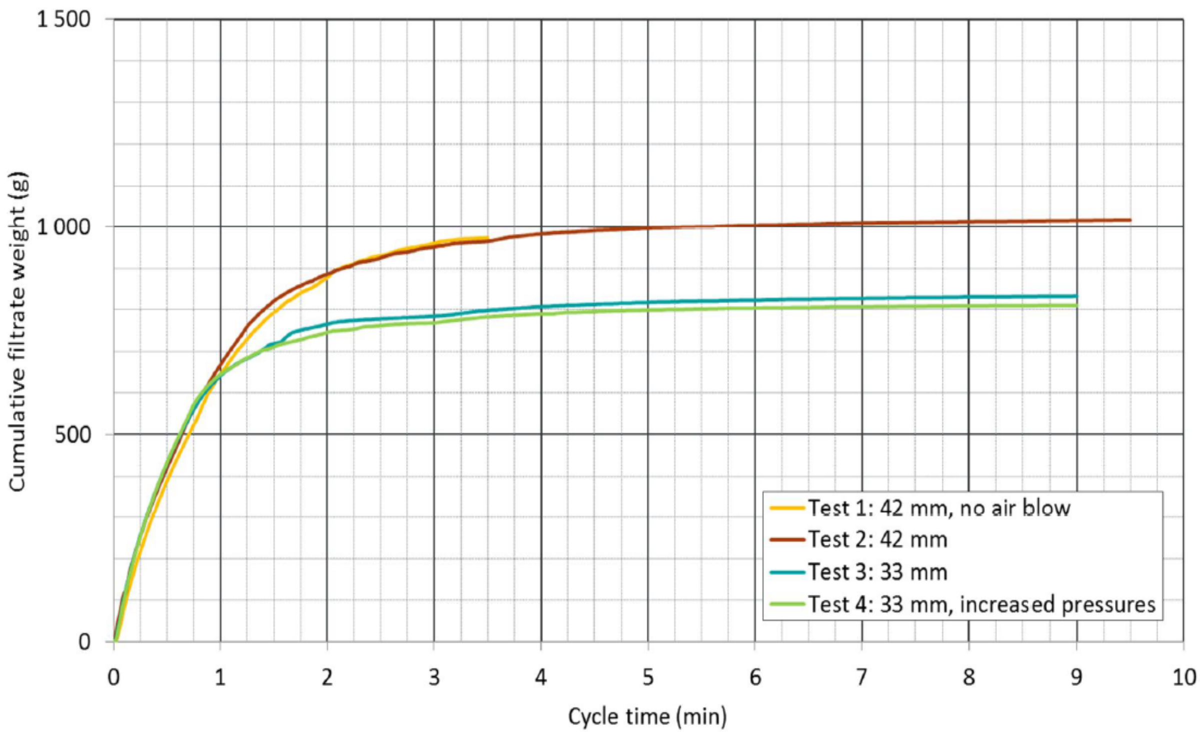

Figure 4. VPA filtrate curves for the 4 tests conducted

Table 4. Summary test results VPA

	Test 1	Test 2	Test 3	Test 4
Dry cake weight (g)	1002	1046	836	829
Dry cake density (kg/l)	2.40	2.50	2.55	2.52
Filter cake rest moisture (%)	11.6	7.6	6.7	6.2
Cake thickness (mm)	42	42	33	33

Filtration

It was found that the material dewatered with an effective filling time of 3 minutes for a 42 mm cake and 2 minutes for a 33 mm cake, as seen at the point where the filtrate curves first flatten (Figure 4). This point represents when the feed pressure created by the pump can no longer contribute to the dewatering of the slurry.

Membrane Compression

The membrane and filter plates are important parts regarding filtration process. The membrane compression pressure was applied for 30 seconds prior to the introduction of the filter cake air blow air and was maintained at 1 bar above the filter cake air blow pressure during air blow, to compensate for any filter cake volume reduction during air blow, thus eliminating filter cake cracking which leads to loss of drying efficiency. Very little filtrate came out during the membrane compression, this indicates that the filter cake is incompressible.

Air Blow

In Figure 5 the filter cake rest moisture is shown as a function of air blow time. The total air blow time was 6 minutes and the moisture contents at shorter air blow times were back calculated from the filtrate volumes collected. After 6 minutes of air blow the filter cake moisture was reduced to 6-8 % w/w, with the lowest rest moisture 6.2 % reached in test 4 with thinner chamber and higher pressures.

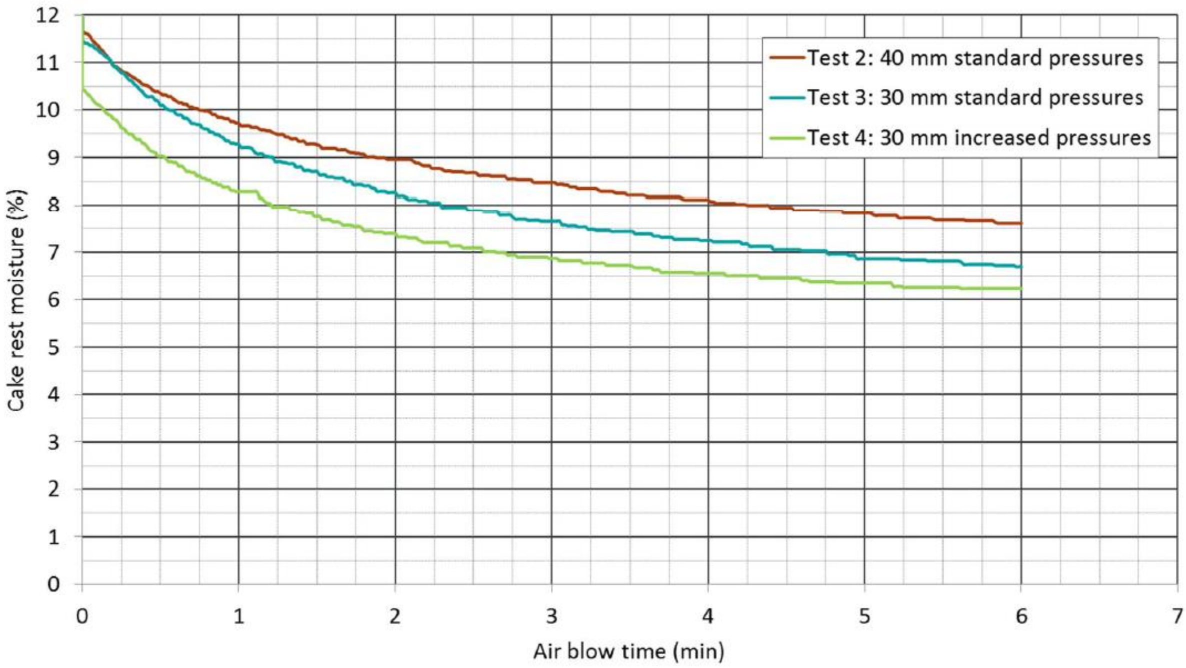

Figure 5. VPA dewatering curves for tests 2-4

Filtrate and Filter Cake

The filtrate was slightly turbid during the first seconds of filtration, but then it became clear. The filter cake was a bit soft/plastic in test 1 where no air blow was applied. In all other tests, the cakes were brittle and dry, with good cake release from the filter cloth.

Filter Cake Dry Density

The filter cake dry density for the material was found to be approximately 2.5 kg/l. This value is close to the expected value of 60 % of dry solids density which indicates that the filter cake packed well.

Conclusion

As mentioned by Townsend [2003], the automatic pressure filters have become widely used in the minerals and metallurgical industries during the last 20 years. Their widespread acceptance has been due to the need for superior process results when dewatering finer materials. This has been discussed by a great number of authors in literature. The aim of this work was to investigate the possibility of zinc concentrate dewatering for reduce the moisture content to 7% with a laboratory vertical plate airblow (VPA filter). Some conclusions can be drawn:

Pressure filtration is a popular choice due to its efficiency and adaptability for a wide range of concentrates. The sample presented dewatered well and is suitable for VPA filtration. In general, for treatment of 6 dry t/h at feed concentration 50 % 1 x VPA1030-28 is recommended to reach the requested 7 % rest moisture, using standard pressures (feed 6 bar, compression 8 bar, air blow 7 bar). The slurry can most likely be thickened to more than 50 %. A thicker feed slurry is beneficial for the filtration and would reduce the cycle time and lower the rest moisture. As a result, it can be-concluded that the filtration method effectively works on the dewatering of zinc concentrate. The conducted experiments demonstrate the possibilities of zinc concentrate dewatering in Erma Reka Concentrator by VPA pressure filtration using 1 x VPA 1030-28.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the authors.

Acknowledgements or Notes

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