PRE-CONCENTRATION OF SILICATE ZINC ORE USING DENSITY AND MAGNETIC CONCENTRATIONS

*D. José Neto[1] and M.G. Bergerman[1], A.D. Souza[2] and E.L.C. Martins[2] and V.Metsavaht[2] and J.L.C. Bechir[2] and L.M.C. Lopes[2] and M.M. Lopes[2] and C.J. Freitas Neto[2] and J.M.C. Melo[2] and C.A.M. Oliveira[2] and L.M. Resende[2]

[1]Mining Engineering Department of São PauloUniversity
2373 Prof. Mello Moraes Avenue
São Paulo - SP, Brazil 05508-030
*(*Corresponding author: dimasnetosri@gmail.com)*

[2]Votorantim Metais S/A
Km 65 LMG 706 Highway
Vazante – MG. Brazil 38780-000

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ABSTRACT

The pre-concentration consists on the previous discard of a fraction of the mineral processing plant feed with few or none quantity of the mineral of interest, reducing the mass to be processed in the downstream operations, as well the capital and operational costs. In this context, this study aims to verify the susceptibility of the silicate zinc ore from Votorantim Metais, Vazante/MG (Brazil), for pre-concentration by density and magnetic methods. For this purpose, tests have been developed in a magnetic roll separator operating under high field (10,000 gauss) and also on sink/float in dense liquids varying between 2.75 to 2.95 g/cm³ and in coarse particle size: + 6,35, - 6,35 + 3,35 e -3,35 + 1,18 mm. The former results show the possibility to discard more than 50% of the plant mass and zinc metallurgical recoveries above 90%. It also shows that the discard of contaminants, as MgO, can achieve 80%. The results for the magnetic separation have not been meaningful in comparison with the density separation.

KEYWORDS

Pre-concentration, Zinc, Density Separation, Magnetic Separation

INTRODUCTION

According Harkki (2014) the main challenges of modern concentration plants are related to:

i. Processing ores with increasingly lower grade, that exhibit complex mineralogical associations and degree of liberation into the finer particles, which require more elaborate comminution operations and various stages of concentration, increasing installation costs and operation of the plant (Bergerman, José Neto, Tomaselli, Maciel, Del Roveri, & Navarro, 2014).

ii. Management and disposal of processing tailings. Low grade ores generate large amounts of tailings, which are usually stored in containment dams, which are subject to the risk of rupture and have high capital and operating costs (Girodo, 2007).

iii. Shortage and water management. Water scarcity, the necessity to accomplish the legal requirements and the cost of payment for the use of water, will influence directly in mineral production. So wherever possible, the water used in the process, must be recycled and reduced, aiding to reduce "new water" consumption and funding costs (Andrade, Sampaio, Luz, Andrade, Santos, & Grandchamp, 2006).

iv. Energy efficiency. According to Lessard, Bakker and Mchugh (2014), the size reduction operations are the stages of higher energy consumption. For low grade ores and high dilution, most of the required energy is consumed in the grinding of material without economic value, which makes the comminution inefficient and with high operating cost.

An alternative currently used to prevent or minimize the problems already mentioned is to use pre-concentration of the ore before the costly stages, more specifically in grinding. Thus, there is a previous discard of a fraction of the liberated or partially liberated gangue with little or any quantity of metal of interest, reducing the mass to be fed in the mill and in the subsequent operations. This brings a range of benefits to the mine and plant, as reported in Table 1.

Table 1 - Benefits of pre-concentration. Not all of these benefits are occurring simultaneously and depend on the specific application (Source: Adapted from Bergerman *et al*., 2014; Cresswell, 2001; Grigg & Delemontex, 2015)

Benefits	Cause
Reducing energy consumption per ton of metal produced	With the removal of gangue, it reduces the mass fed into the mill, not spending energy grinding material that is not of interest, thus reducing the required power. Further, usually higher WI material is discard, which decreases the specific consumption of the grinding circuit.
Increasing tailing dam life	A smaller volume of gangue is processed; therefore the amount of tailing generated to be disposed in the dam is lower.
Reusing waste	As the waste of the pre-concentration is coarse and easily dewatered, it can be used for paving roads, as loan material (dump), filling galleries (backfill) and depending on their characteristics, it can be sold as by-product generating profits.
Reducing water consumption	There is less mass to be treated.
Increasing mine life	Rejecting part of the gangue, the mine cut-off grade decreases, which allows the exploitation of marginal ores and as a consequence there is the expansion of the reserves.
Positive impact on flotation	Pre-concentration eliminates fluctuations in the grade of the flotation feed throughput. The consumption of reagent is susceptible of being optimized, and the circuit can be simplified with possible cleaner and/or scavenger cells reduction.
Positive impact on the thickening	Reduction of the thickening unit capacity demand and consumption of flocculant, particularly in the tailings, which has been reduced.
Increase the production	The feed throughput of the plant is lower, but offer better grade. Thus, it is possible to produce the same amount of metal at lower feed rates, getting margin for the increase in production without requiring expansion of the capacity of the plant installed.

Based to the this premise, it is possible add some of the various existing mineral processing techniques, before the conventional concentrator, as a standard of good practices to improve the quality of feed at the beginning of the treatment plant. The main techniques used are gravimetric methods (dense medium cyclones, drum separator, conic separator, traditional jigs and pressure jigs), ore sorting, magnetic separation (drum separator) and coarse screening. It even may be done after preferential blasting in mining (Grigg & Delemontex, 2015).

The pre-concentration has been applied in precious metal, uranium and suphides mines worldwide. In Brazil, this practice is incipient but there are several current studies and industrially, just the Maracas Vanadium S/A uses a magnetic pre-concentration, with drum separators in order to separate the magnetite-pyroxenite from the silicate gangue. The process achieves a mass recovery of 68% to 81% vanadium and a reduction of 50% of silicate gangue (Costa, 2014).

Others examples of industrial applications for pre-concentration are shown in Table 2.

Table 2 - Industrial applications of pre-concentration and process performance

Pre-concentration method	**Ore type**	**Mine Localization**	**Feed size (mm)**	**Mass rejected (%)**	**Metal recovery (%)**	**Reference**
DMS cyclone	Ni sulphide	Phoenix/Bostwana	25 ~ 1	60	85	Morgan, 2009
Coarse screening after preferential blasting	Au e Cu sulphide	Telfer/Australia	- 20	60	> 80 (both Au e Cu)	CRC ore, 2016
Pressure jig	Polymetallic (Ag, Zn, Pb)	Pirquitas/Argentina	12 ~ 2	50	80 ~ 90	Grigg and Delemontex, 2015
Ore sorting	Wolframite pipes in quartz	Wolfram Camp/ Australia	100 ~ 15	90 ~ 95	80 ~ 85	Lessard, Bakker and Mchugh, 2014
Magnetic separator	Ni associated with pyrrhotite	Whistle/Canada	5 ~ 2,5	38	80	Vatcha, Cochrane and Rousell, 2000

Motivated by the benefits of discard of the still coarse gangue, Votorantim Metais S/A, Vazante/MG unity, has been developing a series of studies to evaluate the applicability of pre-concentration to its operations. This work is part of such studies and aimed to verify the susceptibility of silicate zinc ore the pre-concentration using density and magnetic techniques.

METHODOLOGY

Three representative samples of Zn ore from Votorantim operations were studied:

- Usicon W: with high Zn content (18.24%);
- Usicon C: low Zn content (5.76%);
- *Extremo Norte*: with high content of Zn (20.77%) and low Fe content (2.42%).

The samples were colected at the primary crusher feed of Votorantim Metais in Vazante, and were sent to the Mineral Processing Laboratory in São Paulo University, where they were comminuted on roll crusher until all the material was passing in an aperture size of 12.7 mm. Then the samples were homogenized and sub-samples of approximately 1 kg wore taken for granulometric analysis by dry sieving using aperture size of 9.5 mm, 6.35 mm, 4.75 mm, 3.35 mm, 2.36 mm, 1.68 mm, 1.18 mm and 0.85 mm. Products obtained in the sieving were quartering and sent for chemical analysis. The remaining samples were separeted into aliquots of approximately 10 kg, reserved for the next steps.

For the test sink and float in heave liquids, 1 kg of material was prepared in each of the following fractions size: + 6.35 mm, - 6.35 + 3.35 mm and - 3.35 + 1.18 mm, for the three samples tested. The fine fraction, below 1.18 mm, was discarded for being too thin to density separations methods with technologies planned for industrial use.

Each fraction described above was separated in three different densities. The densities adopted (Table 3) were chosen based on the specific weight of main minerals present in the samples, willemite (ρ = 3.9 ~ 4.2 g/cm³), dolomite (ρ = 2.85 g/cm³) and hematite (ρ = 4.9 ~ 5.3 g cm³).

Table 3 - Densities for the laboratory tests and correspondent dense medium used

Density (g/cm³)	**Dense medium**
2,75	Tribromoethane ($CHBr_3$) diluted with alcohol
2,85	Tribromoethane slightly diluted with alcohol
2,94	Tetrabromoethane pure ($CHBr_2CHBr_2$)

The procedures of the tests as well as the safety procedures taken during the tests are detailed in texts of Sampaio and Tavares (2005); Chaves and Chaves Filho (2013).

The medium density, when diluted, was systematically checked before each test, with the aid of volumetric flask and scale.

Figures 1 and 2 illustrates the procedures of the tests. It is important to note that as the floated in 2.85g/cm³ produced low mass for the fractions of the sample *Extremo Norte*, it was decided to take this density as the smallest and adopted 2.9 g/cm³ as intermediate (Figure 2).

For the magnetic separation, 10 kg of each sample were processed by the magnetic separator drum (model: RE – 5/04-1 of Inbrás). A field of 10,000 gauss and a drum rotation of 80.8 rpm was used. The particle size of the test feed was - 12.7 mm for the three samples.

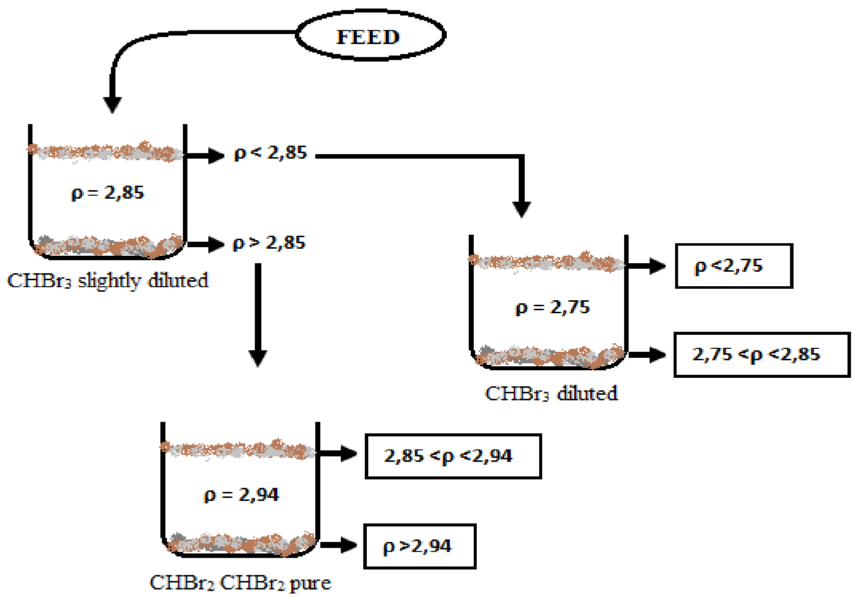

Figure 1 – Procedure for the sink/float test for Usicon W and Usicon C samples

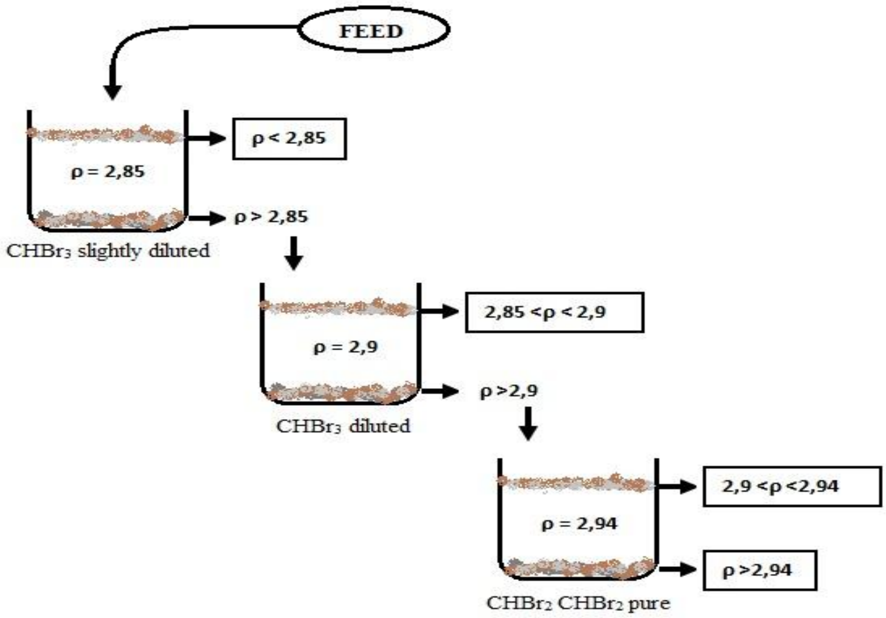

Figure 2 - Procedure for the sink/float test for the *Extremo Norte* sample

RESULTS AND DISCUSSION

The data by chemical analysis shows that the Zn and MgO, the main contaminant, are distributed quite homogeneously in all size fractions, and have proportional distributions to the mass of each fraction. This size behavior was observed for the three samples.

The results of the tests sink/float point to the density 2.94 g/cm³ as more promising for the three samples, as provided sink products with excellent recovery of Zn associated with the lowest MgO recoveries.

Figures 3, 4 and 5 shows the results for the samples Usicon W (- 6.35 + 3.35 mm) Usicon C (+ 6.35mm) and *Extremo Norte* (+ 6.35 mm) respectively. Although other size fractions test also presented excellent separation performance, the fractions that stood out in terms of compromise between better recovery of Zn and lower MgO recovery selected.

The curves mass sinking and floating should be read in the main axis and Zn and MgO curves should be read in axis recovery.

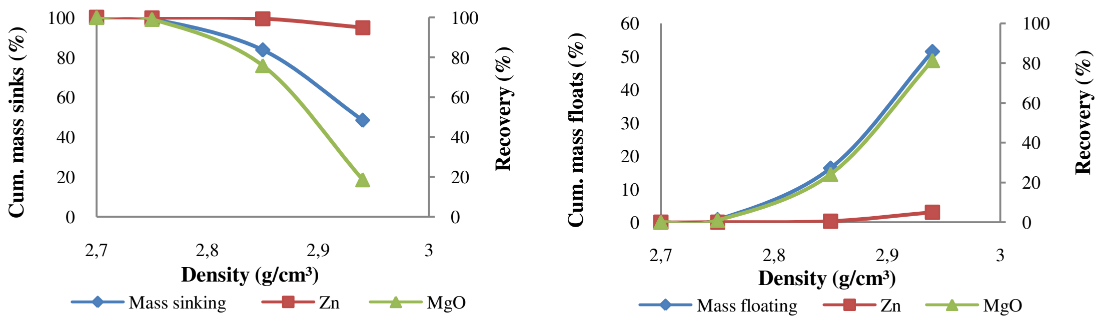

Figure 3 – Separability curves in the sink/float test, sample Usicon W (- 6.35 + 3.35 mm)

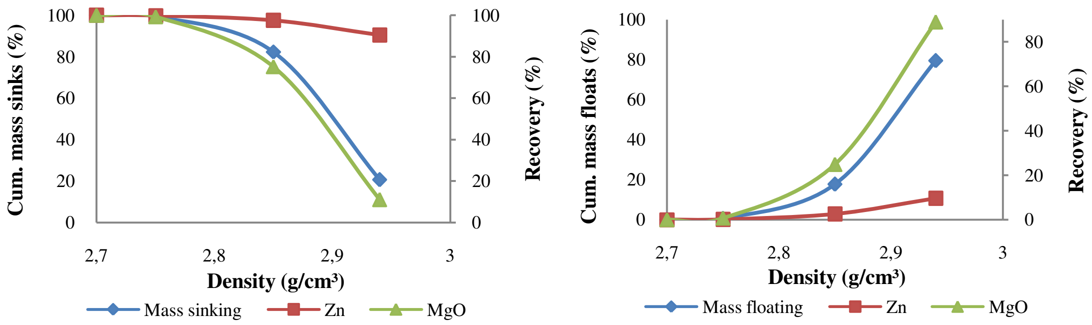

Figure 4 – Separability curves in the sink/float test, sample Usicon C (+ 6.35 mm)

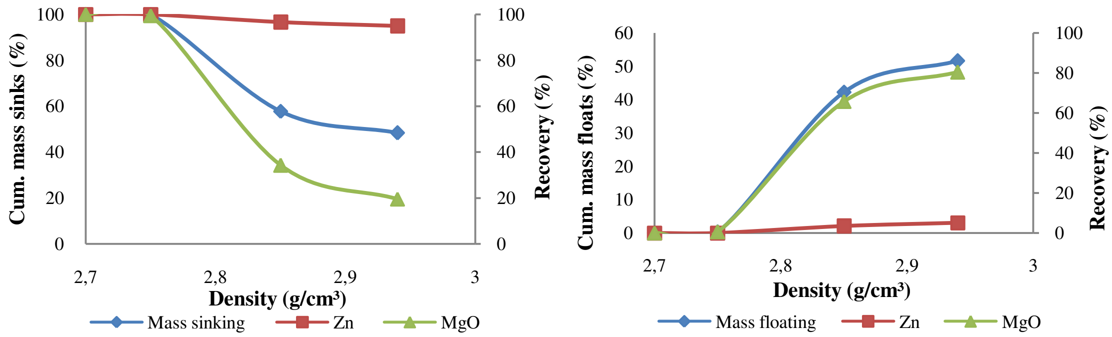

Figure 5 – Separability curves in the sink/float test, sample *Extremo Norte* (+ 6.35 mm)

For Usicon W samples (-6.35 +3.35 mm) and *Extremo Norte* (+6.35 mm), the results indicated the possibility of disposal of approximately 50% of the mass in the floated 2.94 g/cm³, containing nearly 80% of MgO, with only 5% of Zn. Related to the Usicon C sample (+6.35 mm) is possible discard almost 80% of the mass of the float same density, with more than 80% of the MgO. In sink products in the three samples were observed Zn recovery around 90%. This suggests that adoption of a dense mean separation stage becomes technically satisfactory in order to reduce the amount of dolomite feeding rate of the plant. However, tests on a pilot scale and economic viability analysis must be performed to verify the feasibility of a possible industrial installation.

The results of magnetic separation can be seen in Table 4. Note that there were no enrichment of Zn, neither MgO reject as significant as obtained in the dense medium separation.

Table 4 - Results of magnetic separation

Usicon W										
Produto	Massa (g)	Massa (%)	Teores (%)				Distribuição (%)			
			Zn	Fe	Pb	MgO	Zn	Fe	Pb	MgO
Magnético	2.360,00	21,26	16,49	17,59	0,33	4,29	17,43	60,90	8,58	15,74
Não magnético	8.740,00	78,74	21,09	3,05	0,95	6,20	82,57	39,10	91,42	84,26
Alim. Calculada	11.100,00	100,00	20,11	6,14	0,82	5,79	100,00	100,00	100,00	100,00

Table 4 - Results of magnetic separation (continued)

Usicon C										
Produto	Massa (g)	Massa (%)	Teores (%)				Distribuição (%)			
			Zn	Fe	Pb	MgO	Zn	Fe	Pb	MgO
Magnético	1.960,00	17,35	15,93	11,58	0,19	4,99	63,76	62,95	19,00	14,45
Não magnético	9.340,00	82,65	1,90	1,43	0,17	6,20	36,24	37,05	81,00	85,55
Alim. Calculada	11.300,00	100,00	4,33	3,19	0,17	5,99	100,00	100,00	100,00	100,00
Extremo Norte										
Produto	Massa (g)	Massa (%)	Teores (%)				Distribuição (%)			
			Zn	Fe	Pb	MgO	Zn	Fe	Pb	MgO
Magnético	580,00	5,24	17,26	15,95	0,23	4,05	4,55	33,92	4,50	2,94
Não magnético	10.480,00	94,76	20,04	1,72	0,27	7,40	95,45	66,08	95,50	97,06
Alim. Calculada	11.060,00	100,00	19,89	2,47	0,27	7,22	100,00	100,00	100,00	100,00

CONCLUSIONS

- In all the samples studied, we obtained a significant disposal of dolomitic gangue in the float (about 50% in the samples Usicon W and *Extremo Norte* and almost 80% in Usicon C) with Zn recoveries on the order of 90% in sink.
- The best density cut obtained was 2.94 g/cm³.
- The magnetic separation was not efficient in terms of Zn/MgO coarse separation.
- The application of a separation step in dense mean is technically satisfactory. However, tests on a pilot scale and economic viability analysis must be performed to verify the feasibility of the industrial plant.

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