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Pre-Enrichment of Lead-Zinc Leaching Tailings by Hydrocyclone

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Abstract: In this study, pre-enrichment of a typical lead-zinc leaching plant solid tailings were investigated. After the leaching process, due to the decrease in the grain size of the residual minerals (filter cake) and the deterioration of the mineral crystal structures, a concentrate with high recovery for lead (Pb) and zinc (Zn) could not be obtained with mineral enrichment methods / machines such as flotation, multi-gravity separator (MGS), shaking table and Knelson separator. It was determined that the Pb and Zn minerals were concentrated in very fine fractions (<75 µm) by chemical analyzes according to grain size fraction. Thus, it was decided to perform the enrichment method according to the grain size classification and 150 micron sieve and hydrocyclone were used respectively in the enrichment process. After the sieving, a concentration (51.35% by weight) was obtained with 86.64% Pb and 64.84% Zn recoveries. The enrichment process was continued with a series of hydrocyclone experiments using the obtained pre-concentrate. The highest recoveries for Pb and Zn with hydrocyclone experiments were obtained as 71.18% and 52.6%, respectively. As a result, it was found appropriate to disperse the agglomerated coarse sized grains using a roller and/or bar mill prior to sieving to obtain a concentrate with higher recovery.
Key words: Lead, Zinc, Leach tailing, Hydrocyclone, Mineral processing, Mineral enrichment.

Kurşun-Çinko Liç Atıklarının Hidrosiklon ile Ön Zenginleştirmesi

Öz: Bu çalışmada, tipik bir kurşun-çinko liç tesisi katı atıklarının ön zenginleştirilmesi araştırılmıştır. Liç işlemi sonrasında kalan minerallerin (filtre keki) tane boyutunun büyük oranda düşmesi ve mineral kristal yapılarının bozulması sebebi ile flotasyon, multi gravite separatör (MGS), sallantılı masa ve Knelson separatörü gibi cevher zenginleştirme yöntem/makineleri ile kurşun (Pb) ve çinko (Zn) için verimli bir konsantre elde edilememiştir. Tane boyutu faksiyonuna göre yapılan kimyasal analizlerde Pb ve Zn minerallerinin çok ince boyuttaki fraksiyonlarda (<75 µm) yoğunlaştığı tespit edildi. Böylece, zenginleştirme metodunun tane boyutuna göre sınıflandırma ile yapılmasına karar verilmiş ve zenginleştirme prosesinde sırasıyla 150 mikronluk elek ve hidrosiklon kullanılmıştır. Eleme sonrasında % 86,64 Pb ve % 64,84 Zn verimleri ile konsantre (ağırlıkça % 51,35) ürün elde edilmiş ve bu konsantre kullanılarak bir dizi hidrosiklon deneyleri ile zenginleştirme prosesine devam edilmiştir. Hidrosiklon deneyleri ile Pb ve Zn için en yüksek verim sırasıyla % 71,18 ve % 52,6 olarak elde edilmiştir. Sonuç olarak, daha yüksek verimli konsantre ürün elde etmek için aglomera olmuş iri boyutlu tanelerin eleme öncesinde merdaneli ve/veya çubuklu değirmen kullanarak dağıtılması uygun görülmüştür.
Anahtar Kelimeler: Kurşun, Çinko, Liç atığı, Hidrosiklon, Cevher hazırlama, Cevher zenginleştirme.

Introduction

With modern technology and increasing industrialization, consumption of metallic minerals is constantly increasing, as is the case with many minerals. At the same time, new resources for each mineral are still being explored to be produced from earth's crust by mining operations. In addition to this, secondary resources have also begun to be evaluated to meet the growing demand for important metallic minerals such as lead and zinc. Solid tailings, left in the environment in increasing quantities as a result of various mining operations, can be considered as secondary mineral resources. Additionally, some mine tailings containing precious minerals also pose a threat to living things as a result of uncontrolled releases to the environment. Therefore, re-enrichment and recycling of mine tailings is important to meet increasing demands, contribute to the economy and solve environmental problems.

After applying the roasting-leach-electrolytic process to various lead and zinc minerals, solid tailings are left behind in high quantities which can be regarded as secondary mineral resources (Turan et al., 2004; Şahin and Erdem, 2015). Lead and zinc metals can be recovered from these tailings with hydrometallurgical, pyro metallurgical or hybrid methods. Among these, the hydrometallurgical method, which generally requires less energy, is preferred generally. (Jha et al., 2001; Güler et al., 2011;Fujimoto et al., 2016). Çinkom Mining located in Kayseri-Turkey, produced Zinc (Zn), cadmium (Cd), lead (Pb) and silver (Ag) metals by leaching process from oxidized lead-zinc minerals for a long time. As a result of the leaching process, tailings with more than 1.2 million tonnes of lead and zinc content are still stored in the open areas of the Çinkom Plant. (Turan, 2004; Sunkar, 2005; Ruşen et al., 2008;). Because of the heavy metals they contain, leaching tailings are also included in the class of harmful tailings. (Altundoğan et al., 1998; Özverdi and Erdem, 2010). Many research studies have been carried out to recover precious metals such as Pb and Zn from these tailings and to prevent harmful effects to the environment. (Turan et al., 2004; Kul and Topkaya, 2008; Ruşen et al., 2008; Güler et al., 2011; Şahin and Erdem, 2015). However, especially pyrometallurgical methods have high energy and chemical consumption. (Abdel-Aal, 2000; Lin, 2000; Ruşen et al., 2008).

The main purpose of this study is to obtain higher lead-zinc grade concentrates from raw tailings in order to reduce the energy and chemical consumption required in metallurgical methods. Therefore, a series of pre-enrichment studies were performed by conventional mineral enrichment machines such as multi gravity separator (MGS), shaking table, Knelson gravity separator and flotation. However, a concentrate with higher grade and recovery had not been obtained. Because the grain size of the minerals has decreased on large scale and the crystal structures have deformed after leaching. As a result, it has been decided to perform pre-enrichment process according to grain size classification by sieve and hydrocyclone.

Materials and Methods

Solid leaching tailing used in the study was obtained from Çinkom Plant located in Kayseri, Turkey. Grain size distribution determined by laboratory scale wet sieve analysis. In order to understand the crystal structure, Bruker D8 advance X-ray diffraction (XRD) device was used. Chemical composition of leach residue was determined by RIGAKU/ZSX PRIMUS 2 X-ray fluorescence (XRF) device.

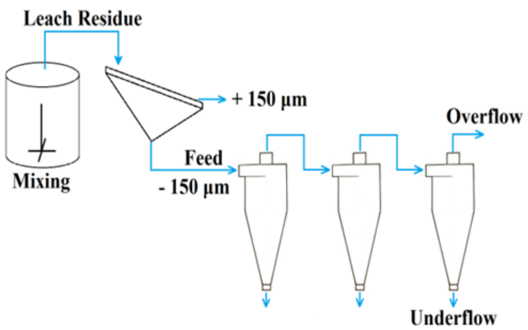

Figure 1: Schematic representation of the used pre-enrichment process.

Table 1: Used experimental parameters for hydrocyclone tests.

Exp. No	Experimental Parameters		
	Product fed to hydrocyclone	Apex diameter (mm)	Vortex diameter (mm)
1		3.2	8
2		4.5	8
3		6.4	8
4		3.2	11.1
5	-150 µm product	4.5	11.1
6		6.4	11.1
7		3.2	14.5
8		4.5	14.5
9		6.4	14.5
10	Overflow of 7. Exp.	3.2	14.5
11	Overflow of 10. Exp.	2.1	14.5
12	Overflow of 7. Exp.	2.1	14.5
13	Overflow of 12. Exp.	2.1	14.5

***Exp**: Experiment.

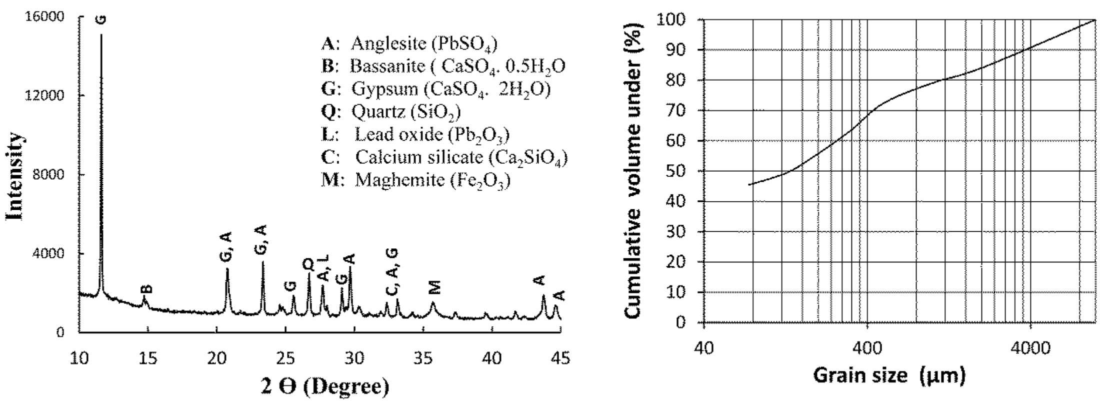

Figure 2: XRD pattern (L: Left) and grain size distribution (R: Right) of Çinkom Plant leaching tailing.

Figure 1 shows the schematic representation of the used pre-enrichment process. As seen in the figure, leaching tailing was added in water with a 20% solid ratio and mixed with a mechanical stirrer at 1200 rpm to allow agglomerated grains to be dispersed before the enrichment studies. After mixing, the suspension was passed through a 150 µm sieve and the remaining product on the sieve was taken as coarse tailing. Hydrocyclone experiments were performed according to the parameters given in the Table 1. After sieving, the pre-enrichment process consists of 3 hydrocyclones connected in series with each other. The first 9 experiments (exps.) are the first stage, the 10th and 12th exps. are the second stage, and the 11th and 13th exps. represent the third stage of hydrocyclone process (Table 1). In all the hydrocyclone exps., the solid ratio and feed pressure were kept constant as 15% and 1.5 psi, respectively.

Results and Discussions

Chemical composition of the leaching tailing is given in the Table 2. The elemental majority consists of lead, zinc, iron, sulfur, silicon and calcium. According to the XRD pattern given in the Figure 2(L), the major mineralogical phases in the tailing were determined to be gypsum ($CaSO_4.2H_2O$), anglesite [$PbSO_4$], lead oxide (PbO), quartz (SiO_2), maghemite (Fe_2O_3), calcium silicate (Ca_2SiO_4) and bassanite ($CaSO_4.0.5H_2O$). Except franklinite ($ZnFe_2O_4$) and bassanite same minerals were detected by XRD for same sample in literature (Şahin and Erdem, 2015; Güler et al., 2011; Özverdi and Erdem, 2010).

Table 2: Chemical composition of the leaching tailing, obtained via XRF measurement.

Assay	Pb	Zn	S	Fe	Al	Si	Ca	Mg	K	LOI
(%, wt)	9.18	6.80	7.77	6.41	2.04	6.64	8.43	0.41	0.59	11.4

*LOI: Loss on ignition

Table 3: Pb and Zn contents of the leaching tailing related to grain size fraction.

Size (μm)	Weight retained (%)	Cumulative undersize (%)	Grade (%)		Distribution (%)	
			Pb	Zn	Pb	Zn
-10000 +2000	15.95	100	2.41	6.26	4.19	14.68
-2000 +1000	4.99	84.05	4.27	8.44	2.32	6.19
-1000 +500	6.71	79.06	3.34	5.52	2.44	5.45
-500 +300	9.89	72.35	1.62	2.72	1.75	3.96
-300 +150	11.11	62.46	2.20	3.02	2.66	4.93
-150 +106	3.53	51.35	4.08	4.52	1.57	2.35
-106 +75	2.34	47.82	5.44	5.34	1.39	1.84
-75	45.48	45.48	16.90	9.08	83.73	60.73
Total	100		9.18	6.80	100	100

Table 4: Results obtained from hydrocyclone experiments.

Exp. No	Overflow				Underflow				Recovery	
	Amount (%)	Solid ratio (%)	Pb (%)	Zn (%)	Amount (%)	Solid ratio (%)	Pb (%)	Zn (%)	Pb (%)	Zn (%)
1	38.72	7.74	20.56	11.14	61.28	57.14	12.65	8.19	50.66	46.22
2	26.74	6.03	22.32	11.38	73.26	47.83	13.30	8.58	37.97	32.61
3	16.66	5.05	22.56	11.26	83.34	31.96	14.35	8.94	23.91	20.1
4	49.34	7.68	20.84	11.08	50.66	62.72	10.72	7.62	65.43	58.6
5	43.21	6.54	21.77	11.34	56.79	59.51	11.11	7.80	59.85	52.51
6	34.38	5.88	22.08	11.35	65.62	38.4	12.38	8.27	48.31	41.84
7	62.99	8.67	20.20	11.06	37.01	61.25	8.09	6.37	80.96	74.71
8	52.93	7.71	21.55	11.24	47.07	62.59	9.15	7.17	72.56	63.78
9	45.87	7.01	23.24	11.71	54.13	53.36	9.34	7.30	67.84	57.6
10	74.4	6.75	21.57	11.17	25.6	54.13	16.21	10.78	79.46	75.1
11	85.63	6.47	22.45	11.38	14.37	45.24	16.79	9.87	89.09	87.29
12	80.4	7.5	21.50	11.05	19.6	53.89	14.87	11.13	85.57	80.28
13	85.21	5.82	22.34	11.42	14.79	47.03	16.64	8.87	88.56	88.12

Although zinc metal was found in the leach residue sample by XRF analysis, franklinite or other zinc minerals were not determined by XRD analysis in this study because of deterioration of the crystal structure of the zinc minerals after leaching process.

Grain size distribution of leaching tailing is given in the Figure 3. It has been found that the sample is dispersed in micronized sizes. The values of d_{80} and d_{50} approximately are 1000 µm and 150 µm, respectively.

Pb and Zn grades of the tailing sample related to grain size fraction are given in the Table 3. As seen in the table, Pb and Zn distributions increase as grain size decreases. In addition, it is determined that 83,73% of Pb and 60,65% of Zn in the sample remains in a fraction less than 75 µm.

Since the majority of the Pb and Zn (86,69% and 64,92%, respectively) are in the -150 µm fraction, the tailing sample was sieved with a 150 µm sieve prior to the hydrocyclone process.

By sieving, a sub-screen product (51,35%, wt) with a grade of 16.33% PbO and 11,61% ZnO was obtained. The product was then used for 1-9 hydrocyclone exps. as feed material.

Hydrocyclone exp. results are given in the Table 4. Accordingly, the highest recoveries with 80,96% for Pb and 74,71% for Zn were obtained from 7^{th} exp. between the first 9 exps. The grade of Pb and Zn were determined as 20,20% and 11,06%, respectively. When the sieving process is included, total yield of the concentrate after 7^{th} exp. is calculated as 32,35%. In addition, the recoveries of Pb and Zn determimed as 71,18% and 52,6%, respectively. The second and third stage hydrocylone exps. results showed that there was no significant change in grades. So, there is no need for second and third hydrocyclone stages for same parameters used in this study. Namely, a concentrate with higher grades cannot be obtained when you get concentrate in thinner sizes.

Conclusion

Çinkom Plant leaching tailing was used in this study for pre-enrichment studies by laboratory scale sieve and hydrocyclone process. After sieving a pre-concentrate was obtained with recoveries of 86.66% Pb and 64,51% Zn. Pre-concentrate product was then used for hydrocyclone experiments but enough recoveries for Pb and Zn could not obtained. In order to be evaluated economically, a concentrate with at least 85% recovery should be taken from the whole process. Therefore, grains having size above 1,0 mm can be dispersed mechanically by using roller crusher and/or bar mill. In this way, agglomerated lead and zinc minerals are liberated and can be recovered by classifying according to grain size.

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