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Flotation Characteristics of Lead-Zinc Ore from Besham, District Swat, NWFP, Pakistan

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Metallurgical grade concentrates of lead and zinc, each assaying over 50% metal content, have been produced by two stage flotation from Besham lead-zinc ore. The ore consists of mainly galena (PbS) and sphalerite (ZnS) as economic minerals while Fe-sulphide/oxide, quartz and other silicates are the gangue minerals. The average concentration of galena and sphalerite in head sample is 0.86% and 9.97% respectively. Both galena and sphalerite can be recovered at a feed size of 85-90% passing 74 microns (wet grinding along with 0.5 kg t^{-1} of sodium cyanide) with pulp density of 25% solids. Galena is recovered as a first step by adjusting pulp pH at 9 with lime. Potassium ethyl xanthate is used as collector and D-250 (polypropylene glycol) as frother. The recovery of sphalerite is made by activation with the help of copper sulphate at pH 11 with the same operational condition as that of galena. The final recoveries are over 90% of Lead and zinc from the ore.

Key words: Flotation characteristics, Lead-zinc ore, Besham, Galena sphalerite.

Introduction

Lead-zinc mineralization has been reported near Besham, District Swat, NWFP, Pakistan. The ore is concentrated at two localities, i.e., Lahor and Pazang Butt (1981) described this mineralization as a result of hydrothermal process associated with Lahore pegmatiod/granite complex. Milner (1985) described the geology of the area. Lahor and Pazang lead-zinc deposits are confined within the metasediments and the rock types of both are same with some facies variations. These rocks are folded and faulted due to post depositional tectonic activity of Himalayas. The lower contact of the metasediments is a thrust fault with gneissic rocks. Pre liminary investigations show around 0.6 million tonnes of ore with the indication that sulphide zones may extend further (Sheikh *et al* 1987).

Lead-zinc ores are usually upgraded by flotation processes. The factors which affect the flotation may be the degree of oxidation of the desired sulphide minerals, type and abundance of gangue in the ore. In froth flotation, minerals can be separated by their surface properties and it is affected by the degree of affinity of the minerals for rising air-bubbles within the agitated pulp. It is therefore, possible to make the valuable minerals aerophilic and the gangue minerals aerophobic by adjusting the pulp properties with the help of suitable flotation reagents (Wills 1997).

The present study encompasses the detailed investigation of the flotation characteristics of the ore affecting the flotation variables like feed size, solid-liquid ratio of the pulp, pH, flotation reagents and their consumption. About 100 kg of lead-zinc ore from Lahor and Pazang has been obtained through the courtesy of Sarhad Development Authority (SDA) for the flotation studies.

It can be seen from the average geochemical data of the lead-zinc ore (Table 1) that the concentrations of the metals Fe, Pb, Zn and Cu are expressed as sulphides while that of others as oxides. The average metal contents of Pb is (0.75%) and Zn (6.70%) classify the ore as lead-zinc ore. Cu concentration is 0.11% pointing out to be a lead-zinc-copper ore (Wills 1997). Among alkali metals, CaO (2%) is mainly associated with carbonates, whereas Al_2O_3 (~23%) and SiO_2 (~18%) are mainly associated with feldspars, silicates and free quartz.

The bulk mineralogy of the head sample was established with the help of XRD analysis. Four mineral phases of interest were identified. These minerals are: galena (PbS), sphalerite (ZnS), pyrite (FeS_2) and quartz (SiO_2).

Materials and Methods

A bulk ore sample for flotation was prepared by subjecting about 25 kg of the ore to a primary jaw crusher set at 1/2" size and then secondary crushing was carried out by roll crusher to a product size of 4-6mm. From this, a representative ore sample of ~1/2 kg obtained by riffling was ground to 200 mesh in pestle mortar and reserved for further chemical and mineralogical studies. From rest of the ore, over two dozen samples, each weighing one kg were prepared for wet grinding in rod mill for flotation studies. The representative ore sample of 200 mesh size was analyzed for major oxides and

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sulphide by conventional wet analytical techniques whereas minor and trace elements were determined by AAS (Hitachi Z-2000). Qualitative analysis of major and trace elements were also performed on X-ray fluorescence (JEOL 603 JSX).

The identification of mineral phases were carried out under stereo microscope in cuttings and polished sections. Sulphide and oxidized phases were identified by the colour change under microscope. Standard staining method was used to identify carbonates of Ca and Mg. Further confirmations of these mineral phases were made through XRD studies (Siemens D5000).

Studies on mesh of liberation was carried out by grinding one kg of ore in a ball mill for 30 min and sieving the ground material to obtain various size fractions. Each size was subjected to examination under microscope for counting the number of liberated and locked mineral particles of galena and sphalerite.

Results and Discussion

Several processes have been developed for the separation of galena (PbS) from (ZnS) sphalerite, but by far the most widely used method is that of two-stage selective flotation, where the zinc and iron minerals are depressed, allowing the galena to float, followed by the activation of the zinc minerals in the lead tailings to allow a zinc float.

The lead-zinc ore under study comprises mainly of galena and sphalerite as economic minerals to be concentrated while Fe-sulphide/oxide, quartz and other silicates are the gangue minerals. Differential flotation tests were carried out in Denver flotation machine (Model D-12) for the separation of galena and sphalerite.

Galena was floated first in the pH range of 7-11. Different xanthates were used as collector for the selection of an effective collector for galena. Similarly a number of frothers were tried to achieve smooth and stable froth. Calculated amount of NaCN was used to depress sphalerite while lime was used to regulate the desired pH of the flotation.

After the removal of galena, sphalerite was activated with a calculated amount of copper sulphate and was in the pH range of 9-13. At this stage other flotation parameters were optimized accordingly for the recovery of lead and zinc.

The rougher concentrations of lead and zinc as obtained above were separately subjected to three cleaning operations to obtain final concentrates. The flotation scheme of the above test work is shown in flotation sheets (Fig 1 & 2). The test variables, such as pH, selection of collector and frother, pulp density and feed size have been studied and optimized.

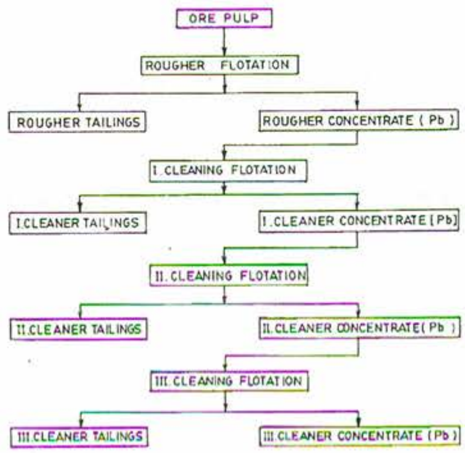

Fig 1. Flow diagram (Lead flotation)

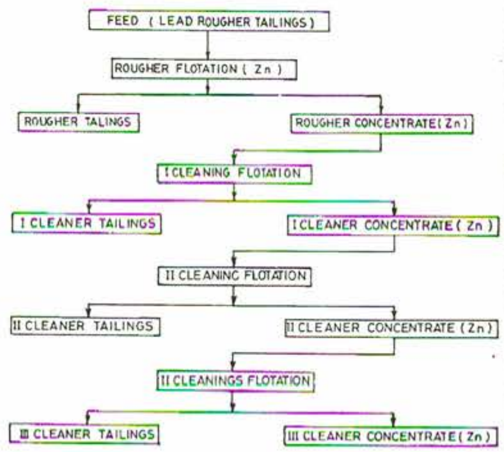

Fig 2. Flow diagram (Zinc flotation)

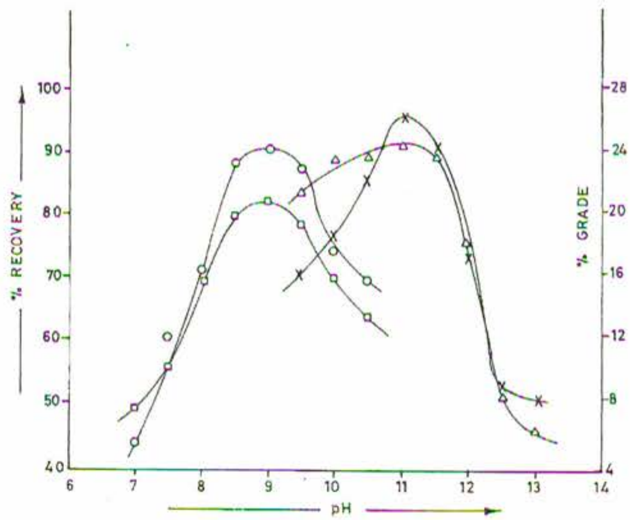

Fig 3. Effect of pH on the grade and recovery of lead and zinc.

PbS Grade
PbS Recovery
ZnS Grade
ZnS Recovery

Effect of pH. Lead flotation is usually performed at a pH between 9 and 11, lime being cheap, is often used to control the alkalinity. Lime also acts as a strong depressant for pyrite, but it can also depress galena to some extent. Hence soda ash is sometimes preferred, especially when the pyrite content is relatively low. However, in the present study, only lime was used to adjust the pH of the pulp. The results thus obtained at varying pH have been plotted in Fig 3. The pH effect of both lead and zinc have been plotted in the single graph for simplicity. It is clear from this figure that under constant conditions of particle size and solid liquid ratio, the maximum recovery of lead is at pH=9.0. Similarly, the maximum recovery of zinc is at about pH=11.0. Further, a small variation in pH shows a significant change in the recovery of Pb. This effect may be attributed to the optimum stability of the xanthates in specific alkaline medium (Leja 1982).

Klassen & Mokrousov (1963) pointed out that pyrite at a pH < 7 forms colloidal hydrated iron oxides [$Fe(OH)_2$ or $Fe(OH)_3$], rendering the surface of pyrite hydrophillic and hindering its interaction with collector. It further expressed that the pyrite depression by lime is related to the formation of a mixed film of $Fe(OH)_3$, $Fe(OH)_2$, $CaSO_4$ and $CaCO_3$ on the surface of pyrite. So the adjustment of pH with lime is nicely looked after the depression of pyrite in the flotation of galena and sphalerite with high percentage of pyrite as gangue material.

Effect of particle size. The particle size at which maximum recoveries can be made, in many cases, is usually the same as of mesh of liberation of the minerals of interest. However, this important parameter needs to be set for the optimum results

Table 1

Chemical composition of lead-zinc ore from Besham, district Swat, NWFP, Pakistan (units: weight %age)

Constituents	Pazang ore	Lahor ore	Average head sample
SiO_2	23.37	17.22	23.29
TiO_2	-	-	0.01
Al_2O_3	-	-	18.07
MnO	-	-	0.01
MgO	-	-	1.12
CaO	-	-	2.02
Na_2O	-	-	1.23
K_2O	-	-	0.30
P_2O_5	-	-	0.13
FeS_2	48.77	32.23	40.19
ZnS	7.77	9.81	9.97
CuS	0.20	0.22	0.22
PbS	0.75	0.83	0.86
Total			97.42

Table 2

Effect of various collectors on the grade and recovery of lead and zinc

Collector (125 g t^{-1})	Grade (%)		Recovery (%)	
	Pb	Zn	Pb	Zn
Ethyl xanthate	20.50	24.91	90.10	90.54
Amyl xanthate	19.10	22.45	87.00	87.92
Isopropyl xanthate	17.90	20.30	86.50	87.88
Z-200(Dithio carbamate)	16.81	18.80	82.80	84.44
Aerofloates	18.0	17.02	86.60	86.50

Conditions: Frother 50 g t^{-1} (D-250), pulp density 25% solids, feed size 74 microns.

Table 3

Effect of various frothers on the grade and recovery of lead and zinc

Frothers	Grade (%)		Recovery (%)	
	Pb	Zn	Pb	Zn
Poly propylene glycol (D-250)	20.05	24.91	90.10	90.54
Methyl isobutyl Carbinol (MIBC)	19.05	20.50	88.71	89.00
Methyl ethylene glycol	14.44	20.40	82.92	88.59
Pine oil	15.15	19.78	83.83	86.21
Creylic acid (Cresol)	15.00	16.92	83.32	84.00
Tertiary alcohol	12.32	18.10	76.02	85.00

Conditions: Frother, 50 g t^{-1} (D-250); pulp density, 25% solids; feed size, 74 microns and collector, 125 g t^{-1} ethyl xanthate

Table 4

Chemical analysis of final concentrates of lead and zinc ore obtained after two stage flotation

Constituents	Lead concentrate (%)	Zinc concentrate (%)
Pb	51.97	0.30
Zn	2.01	49.38
Fe_2O_3	11.12	10.54
Al_2O_3	8.50	9.53
SiO_2	4.50	3.80

when ore comprises complex sulphides and the minerals of interest are finely disseminated (Lager 1985). But in our case the lead-zinc ore seems to be a simple one which means that the recovery of lead and zinc should be close to the mesh of liberation. The data for particle size vs recovery and grade of lead and zinc is plotted in Fig 4. It is clear from this figure that the maximum recovery can be obtained at a feed size of 85% passing of 74 microns. This is of course the maximum liberation limit of both galena and sphalerite. It is interesting to note that the recovery of both galena and sphalerite sharply de-

Table 5
Metallurgical balance for lead flotation

Product	Wt.%	Assay (%)		Assay (%)	
		Pb	Zn	Pb	Zn
III Cleaner conc.	1.15	49.83	1.95	70.02	0.31
III Cleaner tail	0.17	20.87	7.20	4.38	0.17
II Cleaner conc.	1.32	45.51	2.61	74.40	0.48
II Cleaner tail	0.72	7.93	8.00	7.05	0.80
I Cleaner conc.	2.04	32.40	4.51	81.45	1.28
I Cleaner tail	1.47	4.71	10.13	8.55	2.07
Rougher conc.	3.51	20.77	6.89	90.00	3.55
Bulk rougher tail	70.44	0.06	0.71	5.71	6.94
Zinc rougher conc.	26.05	0.15	24.79	4.82	89.69
Head sample	100.00	0.81	7.20	99.99	99.98

Table 6
Metallurgical balance for zinc flotation

Product	Wt.%	Assay (%)		Assay (%)	
		Pb	Zn	Pb	Zn
III Cleaner conc.	9.66	51.56	0.15	69.17	1.80
III Cleaner tail	1.86	23.46	0.34	6.06	0.80
II Cleaner conc.	11.52	47.02	0.18	75.23	2.60
II Cleaner tail	4.82	9.71	0.15	6.50	0.91
I Cleaner conc.	16.34	36.01	0.17	81.73	3.51
I Cleaner tail	9.71	5.90	0.10	7.96	1.31
Rougher conc.	26.05	24.79	0.15	89.69	4.82
Bulk rougher tail	70.44	0.71	0.06	6.94	5.17
Zinc rougher conc.	3.51	6.89	20.77	3.35	90.00
Head sample	100.00	7.20	0.18	99.98	99.99

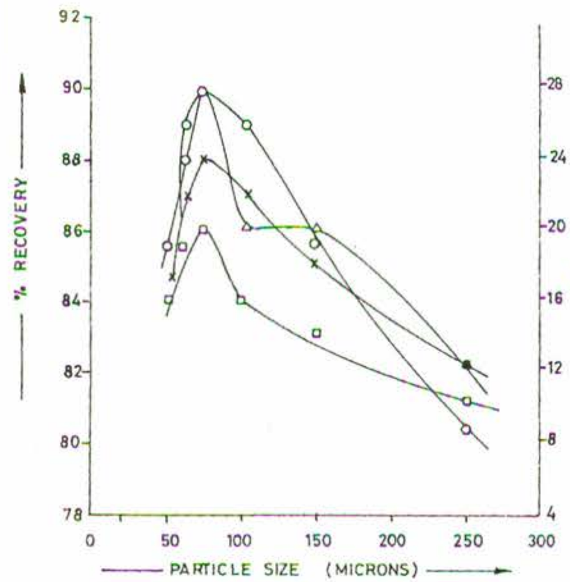

Fig 4. Effect of particle size on the grade and recovery of lead and zinc

—□— PbS Grade —x— ZnS Grade
—o— PbS Recovery —△— ZnS Recovery

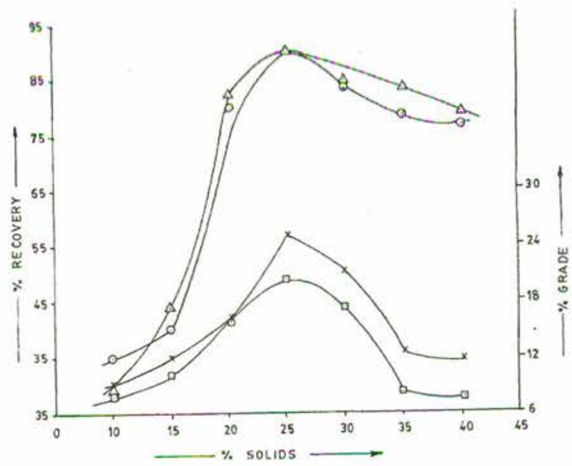

Fig 5. Effect of % solids on the grade and recovery of lead and zinc.

—□— PbS Grade —x— ZnS Grade
—o— PbS Recovery —△— ZnS Recovery

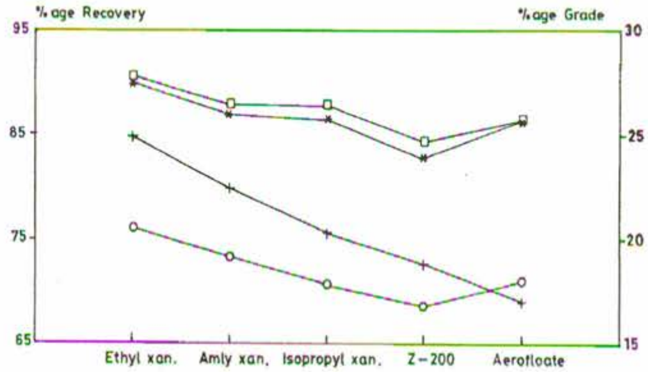

Fig 6. Effect of various collectors of the grade and recovery of lead and zinc.

—o— PbS Grade —+— ZnS Grade
—x— PbS Recovery —□— ZnS Recovery

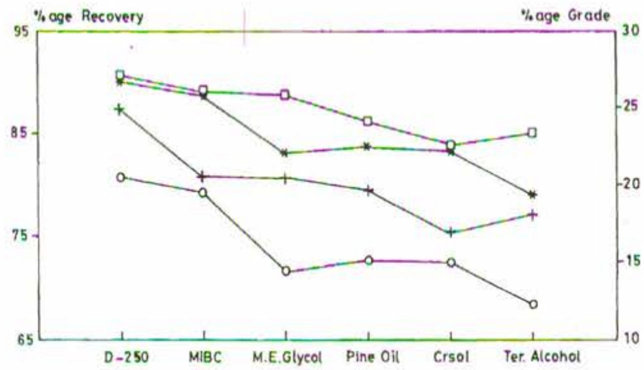

Fig 7. Effect of various frothers on the grade and recovery of lead and zinc.

—o— PbS Grade —+— ZnS Grade
—x— PbS Recovery —□— ZnS Recoverv

that the recovery of both galena and sphalerite sharply decreases at finer particle size, i.e., < 74 microns. Parsonage (1985) pointed out that particles in the sizes range of 20 microns and below have a deleterious effect on the process of flotation.

Effect of pulp density. The solid to liquid ratio also plays an important role in flotation studies and needs to be optimized. The data for percentage solids vs recovery and grade Fig 5. shows that the maximum recovery can be achieved at 20 to 30% solids with an average of 25% solids.

Effect of flotation reagents. A number of collectors have been tested for the recovery of lead and zinc. These collectors when ionize produce positively charged ions of alkali metals and negative xanthate ions. The polar end of the xanthate ion is then adsorbed on the surface of sulphide minerals. Among them are xanthates, carbamates and aerofloats. The recovery and grade of lead and zinc against various collectors have been given in Table 2 and the same data is presented in Fig 6. It is clear from this figure that potassium xanthates (PEX) gives best recovery and grade. Aerofloats are also good collectors and produce better results, however due to their high cost, can not be preferred over xanthates for Besham lead-zinc ore.

Various types of frothers have been used for the recovery of lead and zinc. The data for a number of frothers along with recovery (Table 3) is plotted in Fig 7. D-250 (polypropylene glycol) showed comparatively better results. The combination of potassium ethyl xanthate (collector) and D-250 (frother) in conjunction with cyanide increases the grade as well as the recovery of lead and zinc.

The final concentrates of lead and zinc show 51.56% of Pb with 0.3% of Zn and 49.83% of Zn with 2.01% of Pb (Table 4). Both lead and zinc concentrates therefore falls in the category of metallurgical grade. The metallurgical balance for lead and zinc has been tabulated in Table 5 & 6. Process flow-sheets for the recovery of lead (Fig 1) have been produced based on the experimental results which may be used for the commercial exploitation of the Besham lead-zinc ore.

Conclusion

Besham lead-zinc ore is composed of mainly galena (PbS) as economic minerals while Fe-sulphide/oxide, quartz and other silicates are the gangue minerals. The average concentration of galena and sphalerite in head sample is 0.86 and 9.97% respectively. The recovery of galena and sphalerite from Besham lead-zinc ore is possible through two stage flotation techniques. Both galena sphalerite can be recovered at a feed size of 85-90% passing 74 microns (wet grinding along with 0.5 kg t^{-1} of sodium cyanide) with pulp density of 25% solids. Galena is recovered as a first step by adjusting pulp pH at 9 with help of lime, potassium ethyl xanthate is used as collector and D-250 (polypropylene glycol) as frother. The recovery of sphalerite in then made by activation with the help of copper sulphate at pH 11 with the same operational condition as of galena.

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