# Chapter 32

## BENEFICIATION OF LOW GRADE ORES BY ELECTRO-COLUMN FLOTATION TECHNIQUE

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Abstract. Three types of flotation columns were developed with a column dia of 8.0 cm and a length of 160 cm. The first type consists of an ordinary column fitted with a porous plate at the bottom. The second type consists of two electrodes at the bottom to obtain very fine and uniform bubbles generated electrolytically and the third is a combination of first and second types, i.e. to get both electrolytic bubbles and air from the compressor through porous plate. Three different ores were tested-gold tailings for recovery of scheelite, copper tailings (chalcopyrite) and oxide copper ore. In the case of scheelite and copper oxides, good results were obtained with the first type of column itself, whereas the third type column was found fairly effective in the recovery of chalcopyrite. The variables like the effect of reagent concentration, column height above the feed point, feed flow rate, current density, air flow rate, particle size etc. were examined.

## INTRODUCTION

In recent years the subject of column flotation has gained much importance in mineral processing research and development. Column flotation has been claimed to give better separation than conventional flotation cells particularly on fine materials.

It was proposed to test the response of some tailings carrying low mineral values, finely disseminated, to the treatment in flotation columns developed in the laboratory. One case of oxide copper ore was also proposed for examination with the flotation column.

An attempt has been made to recover chalcopyrite from flotation tailings of the plant of Hindusthan Copper Limited, (H.C.L.), Rakha, Bihar, India. In this plant approximately 700 tons per year copper is lost in the tailings with the ore treatment plant capacity at 1.55 million tons per year. This works out to be around 5% of the total copper production at the above plant. The copper minerals in the tailings were found to be either interlocked with the gangue or in slimes.

Similarly, considerable amounts of tungsten in the form of scheelite is let out in the tailings of gold ore from Kolar Gold Fields, Karnataka, India, without processing. Usual gravity concentration methods tried earlier were found not attractive in achieving good recovery of scheelite.

Another ore tried in this investigation is a mixture of copper oxides where malachite and azurite are predominant. Over 5.5 million tons of copper oxide ore at Malanjkhand copper mine of Hindusthan Copper Limited, India, is presently stock piled in the absence of a suitable beneficiation process.

The gradual depletion of high grade mineral deposits and the need of mineral conservation has turned the attention of mineral industries to develop alternate beneficiation procedures to recover the values from the low grade finely disseminated ores.

## MATERIALS AND METHODS

Three different ores shown in Table I were taken up for the investigation. Sodium diethyl dithio carbamate (DTC) and potassium ethyl xanthate (KEtX) both Analar Grade were used as collectors for copper minerals. Purified Naphthenic Acid and Oleic Acid were used as collectors for scheelite. 0.1N Sodium Sulphate (AR grade) was used as an electrolyte in electroflotation experiments.

Flotation column : Three types of perspex flotation columns were fabricated with a column dia of 8.0 cm and a length of 160 cm. The first type was of an ordinary column fitted with a porous plate at the bottom (Fig.1, Type I). The second type consisted of two electrodes at the bottom (Fig.1, Type II) to obtain very fine and uniform bubbles generated electrolytically. This arrangement is similar to that of simple electroflotation cell. Nickel coated stainless

Table I

| Material | Source | Metal value | Principle gangue |
|---|---|---|---|
| Copper oxide<br>Malachite 91%<br>Azurite 6 %<br>Tenorite 1.8%<br>Cuprite 1.2% | Malanj-khand Copper Mine (H.C.L.) India. | Cu-2.03% | Silicates |
| Copper Tailings | Rakha (H.C.L.) | Cu-0.05% | Silicates<br>Pyrite<br>Pyrrhotite |
| Gold Tailings | Kolar Gold Fields | $WO_3$ 0.038% | Silicates<br>Pyrite<br>Pyrrhotite<br>Arsenopyrite<br>Chalcopyrite |

steel gauze and copper gauze were used as anode and cathode respectively. Both the electrodes ware arranged horizontally just one above the other. Maximum care was taken in the alignment and the gap between the electrodes to minimise power loss and at the same time to avoid any short circuiting of electrodes. The third type of flotation column (Fig.1,Type III) was a combination of first and second types, i.e. to get both electrolytic bubbles and air from the compressor through porous plate. Sintered plate with G-4 poracity cut to 6.5 cm dia and fitted in a funnel was used as a diffuser element. A ratio of 0.8 for the diameter of air diffuser to column was maintained which was recommended as optimum by Narasimhan et.al (1972).

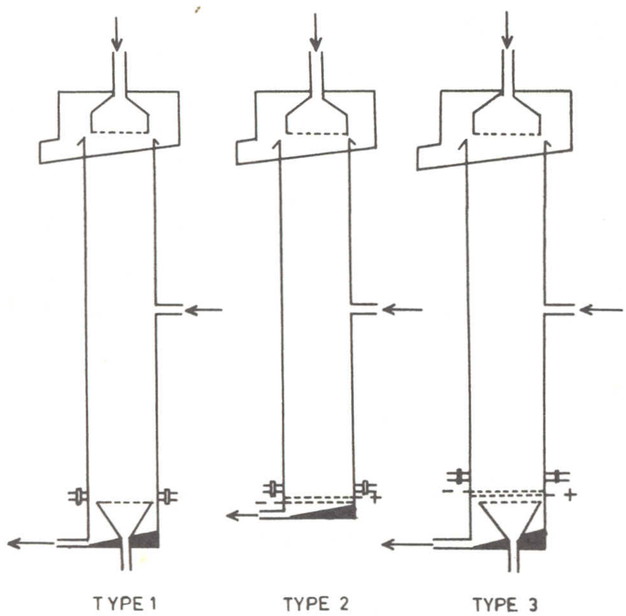


FIGURE 1 : Schematic diagrams of different flotation columns

Constant wash water flow of 1.0 l/min was maintained throughout the experiments from the wash water spray arrangement, which was arranged just above the column to clean the entrained gangue minerals. Provision was made to collect the froth and tailings.

All the experiments were conducted as single stage operations. In each experiment 2 kg of material was conditioned with the depressant, collector and frother in the conditioning tank and pumped through a slurry pump connected to the feed point of the column. Pulp density 20% solids was maintained in the conditioning tank. Pine oil was used as a frother in the case of copper minerals, whereas no frother was added in the flotation of scheelite.

Estimation of copper in the froth and tailings was done in an Atomic Absorption Spectrophotometer (AA 575 Varian Techtron) and that of tungsten by U.V.-Visible spectrophotometer colorimetrically (Young, 1971).

## RESULTS AND DISCUSSION

The chemical and sieve analysis of the copper tailings as received are indicated in Table II.

Table II

Sieve analysis of the copper tailings as received

| S.No. | Particle size Microns | Wt. % of fraction | % of copper |
|---|---|---|---|
| 1 | +150 | 34.8 | 0.050 |
| 2 | -150+106 | 17.4 | 0.038 |
| 3 | -106+75 | 12.3 | 0.028 |
| 4 | -75+45 | 24.2 | 0.050 |
| 5 | -45 | 11.3 | 0.120 |

The analysis of the tailings indicates that 50% of the copper ores present in the finer fraction, i.e. below 75 microns and around 30% in coarser fraction (above 150 microns). Copper lost in the tailings is mostly due to the incomplete liberation of copper mineral and slime coating. An attempt was made to refloat this tailings in a Denver Sub Lab Flotation Cell using KEtX and DTC as collectors. Though the recovery (25.7%) was low, the grade 2.4% copper using DTC as collector was comparatively better than that of KEtX as a collector where recovery and grade are 27.1% and 0.87% respectively. Based on the better selectivity of DTC as collector, it was decided to carry out the further experiments using DTC as collector.

From the liberation analysis it was found that chalcopyrite grains are fully liberated below 75 microns. So copper tailings ground to -75 microns were used as feed to the column flotation experiments. The material was conditioned with 3 Kg per ton of sodium silicate for 10 minutes, followed by the addition of 0.5 kg per ton of pine oil for 5.0 minutes.

Initially, come column flotation experiments were conducted to find out the optimum dosage of collector. Results of the same are shown in Fig.2. From the figure it could be seen that

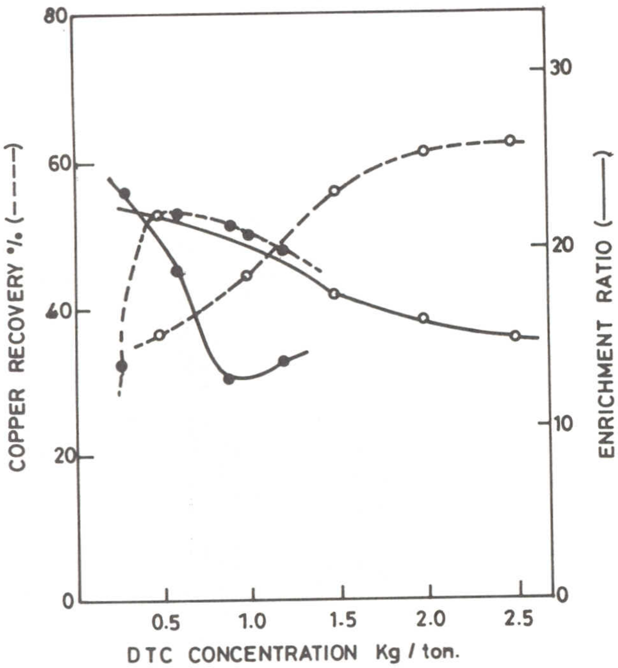


FIGURE 2 : Effect of DTC concentration. Column height 80 cm above feed point, Air flow 7.5 l/min and feed flow 0.6 l/min Copper oxide(o) Copper tailings(•)

the optimum collector concentration for copper oxide and chalcopyrite tailings are 1.5 kg per ton and 0.6 kg per ton respectively. It may be noted that the concentrations are not higher than those experienced in conventional flotation.

The results of the column flotation experiments conducted on copper tailings and copper oxide ores at different air flow rates are shown in Fig. 3. It is observed that the recovery increased with the air rate upto a point and thereafter gradually decreased. Both the grade and recovery were found to be optimum at 7.5 l/min of air flow. Also it could be seen that air flow rate has significant effect on the enrichment ratio of the mineral. Back mixing and turbulance was noticed at higher air flow rates.

Fig. 4 shows the effect of feed (slurry) flow rate on the recovery and enrichment ratio of copper tailings and oxide copper ores. It was observed that as the feed flow increases, the enrichment ratio decreases with no significant change on the recovery of values. It may be due to the effective washing of the froth at minimum feed rate.

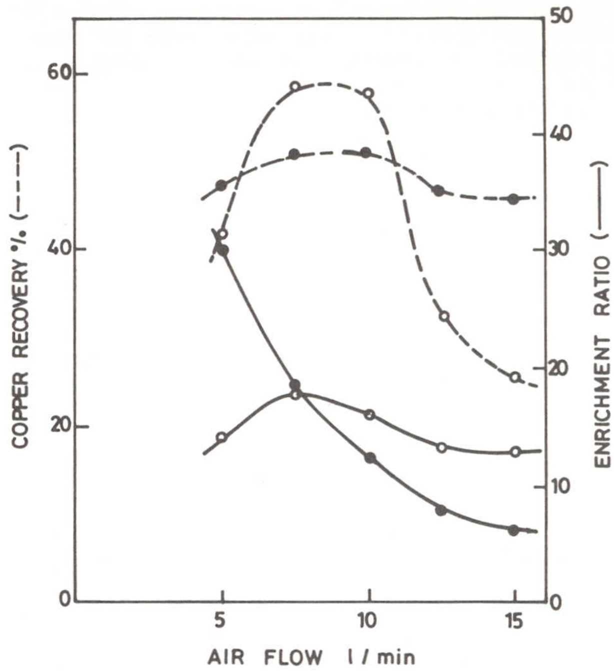


FIGURE 3 : Effect of air flow. Column height 80 cm above feed point, Reagent DTC : 1.5 kg/ton of copper oxide (o) and 0.6 kg/ton for copper tailings (•).

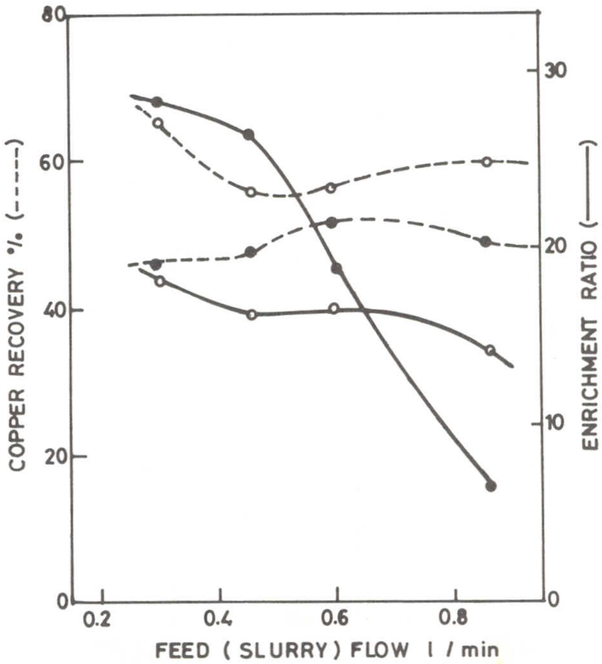


FIGURE 4 : Effect of feed flow. Column height 80 cm above feed point, Air flow 7.5 l/min, Reagent DTC : 1.5 kg/ton for copper oxide(o) and 0.6 kg/ton for copper tailings(•).

The effect of column height above the feed point on the recovery and enrichment ratio for copper tailings and copper oxide ores is shown in Fig. 5. For 8.0 cm dia column a height of 80 cm on either side is considered significant to give optimum performance.

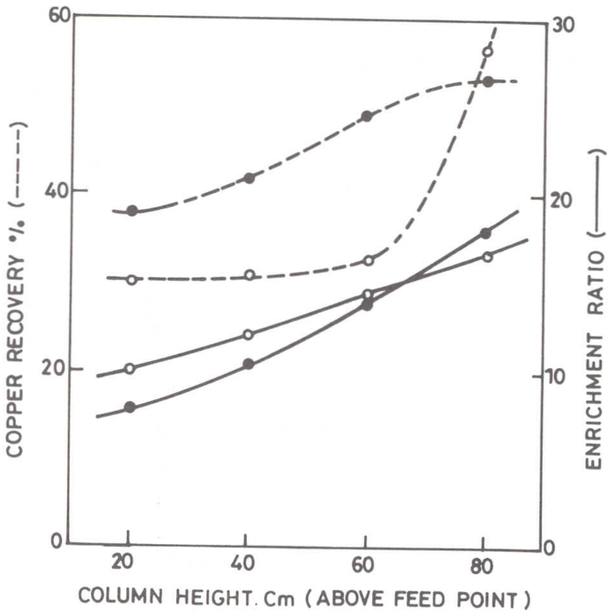


FIGURE 5 : Effect of column height above feed point. Air flow : 7.5 l/min, Feed flow : 0.6 l/min, Reagent DTC : 1.5 kg/ton for copper oxide(o), 0.6 kg/ton for copper tailings(•).

However, from the above results it is clear that the recovery and the enrichment ratio of copper concentrate from both the samples is not so attractive. The same copper oxide ore beneficiated earlier by conventional flotation method has yielded excellent results with an overall recovery of 90% and a grade of 35% copper (Prabhakar et.al 1988). Though the grade was slightly better, the recovery was poor with column flotation (Figs. 2 - 5). Hence further experiments were planned to probe the cause of the low recovery. A set of experiments were conducted with various particle sizes and the results are shown in Table III. From the results it is apparent that the column flotation technique is most efficient for the beneficiation of intermediate size fraction, i.e. -75+45 microns. The low recovery of coarse fraction may be the reason for the overall low recovery stated above. However there appears to be a drastic deterioration in the grade with the finer fraction, but with appreciably higher recovery.

We wish to consider the prolem of poor recovery and grade from copper tailings stated earlier. Based on the earlier experience on the beneficiation of chalcopyrite fines by electro-

Table III

Flotation of various sieve fractions of copper oxide ore with its wt.% in head sample

| S.No. | Particle Size Microns | Wt.% in head sample | % Cu float | % Cu recovery |
|---|---|---|---|---|
| 1 | +150 | 10.66 | 29.1 | 11.3 |
| 2 | -150+106 | 35.98 | 30.1 | 12.7 |
| 3 | -106+75 | 17.21 | 35.0 | 68.7 |
| 4 | -75+63 | 22.18 | 32.1 | 78.5 |
| 5 | -63+45 | 10.82 | 35.6 | 87.7 |
| 6 | -45 | 03.15 | 20.0 | 82.4 |

flotation (Bhaskar Raju and Khangaonkar 1982, 1984), it was assumed that introducing fine bubbles generated electrolytically in the column may help in obtaining better results. Hence some experiments were conducted using electrolytical bubbles in the flotation column type II. The results shown in Table IV have revealed

Table IV

Results with electro-column (Type II) on copper tailings

Reagent DTC : 0.6 kg/ton
Feed flow : 0.6 l/min
Column height : 80 cm above feed point.

| S.No. | Current density $ma/cm^2$ | Enrichment ratio | Copper recovery % |
|---|---|---|---|
| 1 | 47 | 19.3 | 17.8 |
| 2 | 92 | 18.6 | 21.2 |
| 3 | 137 | 17.2 | 27.6 |
| 4 | 184 | 14.3 | 25.4 |

that there is no improvement both in recovery and grade. However, experiments conducted in a combined column type III have shown (Table V) some improvement both in recovery (68%) and

Table V

Results with combined column (Type III) on copper tailings

Reagent DTC : 1.5 kg/ton
Air flow : 7.5 l/min
Feed flow : 0.6 l/min
Column height : 80 cm above feed point.

| S.No. | Current density $ma/cm^2$ | Enrichment ratio | Copper recovery % |
|---|---|---|---|
| 1 | 47 | 42.8 | 57.2 |
| 2 | 92 | 41.4 | 58.4 |
| 3 | 137 | 35.4 | 67.9 |
| 4 | 184 | 31.6 | 57.9 |

grade (2.4%). However these results are inferior compared to those in a simple electroflotation apparatus (Bhaskar Raju and Khangaonkar, 1986). The results for poor metallurgy in column flotation using electrolytic bubbles are complex. Thorough analysis of the hydrodynamics may help in understanding the reasons.

Separate set of experiments were conducted to beneficiate scheelite from gold tailings. Since the column flotation is effective below 75 microns, the material was ground to below 75 microns and used as a feed in column flotation experiments, using column flotation unit Type I. The ground tailings were conditioned with 0.5 kg/ton of lime followed by 2 kg/ton of sodium carbonate and 3.6 kg/ton of sodium silicate with a conditioning time of 10 min after each addition. These values are found to be optimum in preliminary experiments. Oleic acid, naphthenic acid and the combination of both were tried as collectors. 10 min conditioning was maintained after the addition of collector. 1:1 (by weight) Naphthenic acid and oleic acid was found to be very effective collecting system in the presence of above conditions.

During the experiments, it was observed that unslimed ore yielded only 68.2% recovery and an enrichment ratio of 16. Desliming enabled much better recovery (95%) and an enrichment of 50. Hence all experiments regarding the study of air flow, slurry flow, etc. were conducted on deslimed ore. The results are shown in Tables VI to IX. The optimum conditions were

Table VI

Effect of collector (1:1 Naphthenic acid and Oleic acid)

Air flow : 7.5 l/min
Feed flow : 0.6 l/min
Column height : 80 cm above feed point.

| S.No. | Collector kg/ton | Enrichment ratio | % $WO_3$ Recovery |
|---|---|---|---|
| 1 | 0.04 | 42.3 | 73.5 |
| 2 | 0.08 | 51.4 | 88.7 |
| 3 | 0.12 | 52.8 | 91.3 |
| 4 | 0.16 | 45.7 | 92.1 |
| 5 | 0.20 | 39.9 | 90.2 |

observed to be - air flow 7.5 l/min, slurry flow 0.6 l/min., column height 80 cm above feed point and collector 0.08 kg/ton of 1:1 Naphthenic acid and Oleic acid.

A test was conducted for the above scheelite deslimed sample in a conventional Denver Lab Flotation Cell, with the reagent conditions same as above. The recovery was 95% and enrichment ratio was 15.5. It is therefore apparent that column flotation has given a much better grade.

Table VII

Effect of air flow

Feed flow : 0.6 l/min
Collector : 0.08 kg/ton
Column height : 80 cm above feed point.

| S.No. | Air flow l/min | Enrichment ratio | % $WO_3$ Recovery |
|---|---|---|---|
| 1 | 5.0 | 50.1 | 87.4 |
| 2 | 7.5 | 52.5 | 88.3 |
| 3 | 10.0 | 45.3 | 87.8 |
| 4 | 12.5 | 38.6 | 89.1 |
| 5 | 15.0 | 29.0 | 88.5 |

Table VIII

Effect of feed flow rate

Air flow : 7.5 l/min
Collector : 0.08 kg/ton
Column height : 80 cm above feed point.

| S.No. | Feed flow l/min | Enrichment ratio | % $WO_3$ Recovery |
|---|---|---|---|
| 1 | 0.86 | 28.4 | 92.3 |
| 2 | 0.60 | 52.6 | 90.6 |
| 3 | 0.46 | 46.3 | 88.7 |
| 4 | 0.30 | 50.2 | 89.2 |

Table IX

Effect of column height (above feed point)

Air flow : 7.5 l/min
Feed flow : 0.6 l/min
Collector : 0.08 kg/ton

| S.No. | Column Height above feed point, cm | Enrichment ratio | % $WO_3$ Recovery |
|---|---|---|---|
| 1 | 80.0 | 53.9 | 89.2 |
| 2 | 60.0 | 36.9 | 82.8 |
| 3 | 40.0 | 31.6 | 80.6 |
| 4 | 20.0 | 25.8 | 80.0 |

## CONCLUSIONS

1. For the samples of copper tailings, oxide copper ore and gold tailings (for scheelite), it was observed that column flotation yielded better enrichment ratio.

2. It was observed that feed (slurry) flow and air flow have significant effect on the beneficiation of ores in column flotation.

3. For the above materials, column flotation was found to be more effective in the range -75+45 microns.

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