

BENEFICIATION OF KYANITE AND SILLIMANITE

KYANITE and sillimanite have the same chemical composition $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$ and are used extensively in the refractory brick manufacture. Kyanite sillimanite having a minimum 60% Al_2O_3 and less than 1% of iron oxide preferably in the form of 1/2" lumps are required by the refractory industry. Low grade sillimanites from Bihar, Maharastra, Karnataka and Orissa were tested in NML for either upgrading or lowering the iron oxide content of the samples. Depending upon the liberation size, kyanite is usually upgraded by gravity methods when the lighter siliceous gangue comprising quartz and mica are removed. When the gravity methods fail, flotation is employed. Iron oxides are eliminated by either reduction roast followed by magnetic separation or acid leaching.

A. MAHARASTRA SAMPLES

1. Kyanite-Sillimanite Samples from Dahagaon Area, Nagpur

A kyanite-sillimanite sample marked D_2S_1 was received from State Department of Geology & Mining, Government of Maharastra, to produce a refractory grade of concentrate. Complete chemical analysis of the sample was as follows :

Constituent	Assay %
Al_2O_3	40.10
SiO_2	51.67
TiO_2	0.65
MgO	0.49
Fe_2O_3	0.40
CaO	1.36
$\text{Na}_2\text{O} + \text{K}_2\text{O}$	1.31
LOI	4.00

Microscopic examination of the samples indicated that muscovite and quartz formed the bulk of silicate gangue followed by minor amounts of sericite, biotite, chlorite, rutile, tourmaline and some opaques. Kyanite-sillimanite were fairly liberated from the gangue at 100 mesh size.

Tabling tests with the sample ground to 35 mesh yielded a concentrate of 50.7% Al_2O_3 with low recovery. Because of the flaky nature of mica, tests at finer size also did not yield good grade of concentrate.

Flotation tests with deslimed feed (49% passing through 200 mesh screen) produced a concentrate analysing 47.5% Al_2O_3 with 57.1% recovery. When the amount of slimes rejected during desliming was partially reduced, the concentrate analysed 42.08% Al_2O_3 with 77.3% distribution. Flotation test in acidic circuit (pH 2.5) employing sodium sulfonate and lactic acid produced a concentrate analysing 47.0% Al_2O_3 with 71.94% recovery. When citric acid was used in place of lactic acid the concentrate analysed 49% Al_2O_3 with 68.8% recovery. The final concentrate after six cleanings analysed 57.9% Al_2O_3 with only 13.9% recovery.

Examination of the concentrates under microscope always indicated the presence of fine flakes of mica and some quartz grains. Hence further tests were conducted using amines in the first place to float off mica and quartz, followed by kyanite-sillimanite flotation with sodium sulfonates. Then the concentrate was cleaned. The concentrate thus obtained analysed 57.5% Al_2O_3 but the recovery was only 14.5%.

Another sample received from the same department from the same area marked D_2S_2 exhibited

similar mineralogical constitution. The complete chemical analysis of the sample was given as follows :

<i>Constituent</i>	<i>Assay %</i>
Al ₂ O ₃	38.40
SiO ₂	52.00
TiO ₂	0.35
MgO	0.95
Fe ₂ O ₃	0.37
CaO	1.60
Na ₂ O + K ₂ O	1.70
LOI	5.00

Chemical analysis of the sample indicated that the sample was of slightly poorer grade than the other sample. Kyanite and sillimanite were liberated from the gangue at 100 mesh size.

Tabling tests with a feed ground to 65 mesh size and sizing produced a concentrate analysing 43.5% Al₂O₃ with 49.9% recovery in it. Similar tests conducted with 100 mesh grind and sized feed yielded a concentrate of 45.15% Al₂O₃ with 37.7% recovery. Finer concentrate analysed only 35.6% Al₂O₃.

Flotation tests employing citric acid, lactic acid and sulfonate in acid circuit produced best results with a deslimed feed (ground to 56% —200 mesh) wherein the concentrate analysed 50.26% Al₂O₃ with 58.2% recovery. When the concentrate was cleaned for 3 times, the cleaner concentrate analysed 59.9% Al₂O₃ with 37.5% recovery. The examination of the concentrate under microscope indicated that the sample contained about 96% of kyanite. When the refloat cleaner tails were further ground to 100 mesh size and cleaned twice, the concentrate thus obtained also analysed 59.8% Al₂O₃ with a further recovery of 15.3%. Thus the cleaner concentrate and the concentrate obtained from the treatment of the middlings (cleaner tails) amounted to 34.6% by weight analysing 59.8% Al₂O₃ with 52.8% recovery in it.

Flotation tests for floating off muscovite and quartz in the first place, then floating kyanite-sillimanite followed by three cleanings yielded a concentrate analysing 59.6% Al₂O₃ with 42.5% recovery of Al₂O₃. Recirculation of the middlings may increase the recovery by additional 10-15% with the same grade.

This sample responded better than the D₂S₁ sample for beneficiation.

2. Kyanite-Sillimanite from Maharashtra Mineral Corporation

The sample has also been drawn from the Dahagaon area and constituted lumps of 15 mm size with little fines. Complete chemical analysis of the sample was as follows :

<i>Constituent</i>	<i>Assay %</i>
Al ₂ O ₃	49.03
SiO ₂	45.14
TiO ₂	0.22
Fe ₂ O ₃	0.34
MgO	0.41
CaO	1.02
Na ₂ O + K ₂ O	1.13
LOI	2.15

Chemical analysis of the sized products indicated that —200 mesh fines contained only 36.2% Al₂O₃ with 2.8% distribution and contained the bulk of gangue minerals. Microscopic examination and chemical analysis of the hand picked products indicated that 38% of the Al₂O₃ was contributed by micas and the overall kyanite-sillimanite of the sample amounted only to 43.6% by weight.

Heavy media separation tests conducted at sp. gr. 3.2 with —18 mesh crushed product produced a concentrate analysing 54.3% Al₂O₃. Jigging tests at similar size did not produce any good results.

Tabling tests conducted with a sized feed ground to 48 mesh produced a concentrate analysing 58.1% Al₂O₃ with 48.6% Al₂O₃ and 54.7% kyanite recovery. Tabling tests conducted at 100 mesh size produced a concentrate of 59.1% Al₂O₃ with 47.2% Al₂O₃ recovery i.e. 53.2% kyanite recovery in it.

Humphrey's spiral test conducted with —48 mesh ground material yielded a concentrate analysing 52.2% Al₂O₃ with 80.2% Al₂O₃ recovery.

Flotation tests conducted with —65 mesh ground spiral concentrate using lactic acid, sodium sulfonate and sulphuric acid followed by two cleanings

produced a final concentrate analysing 61.1% Al_2O_3 with 67.8% Al_2O_3 recovery.

B KARNATAKA KYANITE

A sample of kyanite from Mavinkere area, Hassan Dist., Karnataka was received from M/s. Best & Co., Madras. The sample was of high grade in nature but had a low pyrometric cone equivalent (PCE) value for use in the refractory industry. The sponsors desired that the reasons for the low PCE be identified and improved. The sample analysed as follows :

<i>Constituent</i>	<i>Assay %</i>
Al_2O_3	64.09
SiO_2	26.28
Fe_2O_3	1.20
TiO_2	0.58
Alkalies	0.64
PCE	1400°C

The ore consisted of two types of minerals viz., kyanite and Corundum. The kyanite was associated with muscovite and quartz. Small amounts of tourmaline and altered minerals, rutile, magnetite were observed with Corundum.

Heavy media separation tests conducted at sp. gr. 3.25 with 1" crushed and sized feed produced a sink product of 29.6% by weight with a PCE value of 1820°C. But from the other products obtained in the test, it was observed that Al_2O_3 content has no direct relationship with the PCE value.

Jigging test with a 4 mesh crushed sample produced a concentrate of 70.6% by wt. and 69.48% Al_2O_3 with a PCE value of 1680°C. When the Corundum bearing portions were hand picked from the 1" crushed ore material, then crushed to 4 mesh and treated in jig, the concentrate thus obtained was 42.9% by weight with assay 62.75% Al_2O_3 and 1820 to 1835°C PCE value. The Corundum poor portion which was hand-picked had a low PCE value of 1500°C only.

Tabling tests with a 35 mesh ground and sized feed produced 49.5% by wt. concentrate assaying 72.76% Al_2O_3 with 1820°C PCE value.

The tests indicated that the minerals that were associated with Corundum had low PCE value which

in turn lower the PCE value of the sample. When the sample was crushed to 35 mesh size, all the low PCE value minerals were liberated and were removed by gravity separation.

C. ORISSA KYANITE

A low grade kyanite was received from M/s. S. Lal & Co., drawn from the Magarmohan Mines, Pallahara area, Orissa and the end product was required for use in the refractory industry. The sample analysed as follows :

<i>Constituent</i>	<i>Assay %</i>
Al_2O_3	51.6
SiO_2	41.2
Fe_2O_3	1.1
TiO_2	1.4
CaO	0.44
MgO	0.41
$\text{K}_2\text{O} + \text{Na}_2\text{O}$	1.6
LOI	1.7

Microscopic examination of the sample indicated that kyanite was the only mineral of that group present, associated with mica and quartz, which were liberated at 48 mesh size.

Tabling tests conducted with the sample ground to 48 mesh followed by sizing produced a coarse concentrate analysing 60.2% Al_2O_3 with 24.1% recovery. Similar test conducted with —65 mesh grind yielded 60.5% Al_2O_3 grade with 25.6% recovery. The other concentrates from both the tests had lower Al_2O_3 value due to the interference of mica during separation.

Flotation tests using sod. sulphonate as collector for kyanite, with 36% —200 mesh grind after desliming and four cleanings produced a concentrate assaying 58.6% Al_2O_3 with 78% recovery. Similar test conducted at pH 4.9 yielded a concentrate of 58.6% Al_2O_3 and 78.0% recovery. For all the above tests extra collector was employed during cleaning also. When no collector was added in cleaning stages, but only lactic acid was used for depressing mica, the concentrate obtained after two cleanings yielded a concentrate of 60.8% Al_2O_3 with 67.3% recovery. Flotation at elevated temperature did not show any improvement. Tests conducted with different

reagent combinations had yielded similar grades, but with low recoveries.

D. BIHAR KYANITES

1. Kyanite from Badia

A low grade kyanite sample was received from M/s. Natural Science India (P) Ltd., for beneficiation studies. The sample was drawn from Badia mine in Dhalbhum area of Singhbhum dist. The sample consisted of lumps upto 200 mm in size and analysed as follows :

<i>Constituent</i>	<i>Assay %</i>
Al ₂ O ₃	45.34
SiO ₂	49.37
Fe ₂ O ₃	0.53
TiO ₂	0.47
Na ₂ O + K ₂ O	1.68
CaO	1.00
MgO	0.38
LOI	1.13
S	Trace.

Microscopic examination of the sample indicated that the kyanite was of massive type and quartz and mica respectively constituted 20% and 9% of the ore and liberation was at 100 mesh size.

Jigging tests with —10 mesh unsized feed produced a concentrate analysing 53.74% Al₂O₃ with 54.1% distribution. Combined operation of jigging (—10+14 & —14+20 mesh) and tabling (—20 mesh product) with the —10 mesh material produced a concentrate assaying 52.58% Al₂O₃ with 43.6% distribution.

Tabling tests with 35 mesh sized feed produced a combined concentrate assaying 54.17% Al₂O₃ with 61.6% recovery. However, similar test with —48 mesh feed yielded a concentrate analysing 53.44% Al₂O₃ with 49.4% recovery.

Flotation tests with 100% —48 mesh feed using lactic acid and sodium sulphonate at a pH of 3 with three cleanings of the rougher float produced a concentrate analysing 60.23% Al₂O₃ with 78.5% recovery. The recovery might improve when the middlings were recirculated. Hence, it may be concluded that the pre-

sent sample may be upgraded for refractory purpose by flotation.

2. Singhbhum Kyanite

A low grade kyanite drawn from Singhbhum and Bakra areas of Singhbhum district was received from M/s. Natural Science India (p) Ltd., for beneficiation studies by gravity methods. The sample consisted of lumps from 400 mm to 40 mm in size. Complete chemical analysis of the run-of-time ore was as follows:—

<i>Constituent</i>	<i>Assay %</i>
Al ₂ O ₃	51.23
SiO ₂	43.20
TiO ₂	1.33
Fe ₂ O ₃	0.70
CaO	0.43
MgO	0.56
Na ₂ O + K ₂ O	1.03
LOI	1.24

Examination of the sample under microscope indicated that quartz & mica were the chief gangue minerals which were liberated respectively at 35 and 65 mesh sizes. Kyanite constituted 80% of the sample.

Jigging tests at 10 mesh size produced a concentrate analysing 55.1% Al₂O₃ with 53.7% recovery. Tabling tests with 35 mesh sized feed produced a combined table concentrate analysing 56.6% Al₂O₃ with 72.35% recovery. Similar tests with 65 mesh sized feed yielded a combined concentrate assaying 60.1% Al₂O₃ with 40.9% recovery.

Flotation tests with 100% —65 mesh size (58% —200 mesh) using lactic acid and sodium sulphonate produced a concentrate analysing 60.4% Al₂O₃ with 62.7% recovery. Flotation tests with longer roughing time followed by cleaning under similar conditions yielded a concentrate analysing 61.1% Al₂O₃ with 82.7% recovery.

3. Kyanite from Rajkharswan Mines

A sample of kyanite from Rajkharswan area, Singhbhum district; was received from M/s. Indian Copper Corporation Ltd., for beneficiation studies. The sample

consisted of lumps ranging in size from 75 to 200 mm and analysed as follows:—

<i>Constituent</i>	<i>Assay %</i>
Al ₂ O ₃	54.90
SiO ₂	40.10
Fe ₂ O ₃	0.39
TiO ₂	1.40
CaO	0.20
MgO	0.13
K ₂ O + Na ₂ O	1.79
LOI	1.13

Microscopic examination revealed that quartz, cordierite and mica formed the bulk of the gangue minerals. Minute inclusions of rutile in kyanite were also observed.

Flotation studies with 50.5% —200 mesh feed employing lactic acid and sodium sulphonate in acid circuit yielded a concentrate assaying 60.4% Al₂O₃ with 83.5% recovery. With two cleanings, the grade of the concentrate had improved to 62.4% Al₂O₃ with 64.5% recovery.

Hydrosizing tests with —48 mesh feed produced a coarse sand analysing 60.2% Al₂O₃ with 56.4% recovery. When the fines and the slimes were further subjected to flotation, a concentrate analysing 60.9 with an additional recovery of 19.5% Al₂O₃ was produced. Thus the coarse sand and the flotation concentrate when combined analysed 60.4% Al₂O₃ with 75.9% recovery.

Tests employing different reagents did not improve the grade, or recovery. Hence it is concluded that hydrosizing and flotation of the sand & slimes would yield the best results.

4. Kyanite from Amda-Lapsu Mines

A poor grade kyanite from Amdalapsu area in Singhbhum district was received from M/s. Indian Copper Corporation for beneficiation studies. The sample consisted of lumps from 10 cms to 1.5 cms. in size without any fines. Complete analysis of the sample, was as follows:

<i>Constituent</i>	<i>Assay %</i>
Al ₂ O ₃	38.2
(Al ₂ O ₃ from kyanite	25.0)
SiO ₂	50.6
Fe ₂ O ₃	3.1
TiO ₂	1.0
CaO	2.4
MgO	1.5
Na ₂ O + K ₂ O	1.15
LOI	2.30

Microscopic examination of the sample indicated that kyanite was of massive and schistose nature. Quartz and mica formed the bulk of the gangue. Minor amounts of sericite and rutile were also observed. Kyanite was fairly liberated at 48 mesh size.

Tabling tests with 65 mesh sized feed yielded a combined concentrate analysing 48.2% Al₂O₃ with 36.2% recovery.

Flotation test with 56% passing 200 mesh screen in a slightly acidic medium employing lactic acid and sodium sulphonate, with five cleanings produced a concentrate assaying 58.4% Al₂O₃ with 45% recovery. When a larger quantity of slimes were rejected from the flotation feed, under similar conditions a concentrate assaying 60.4% Al₂O₃ with 48.8% recovery was produced. Addition of lactic acid during cleaning did not improve the results.

5. Kyanite (Sample No. BT/3) from Lapsoburu, Area

The kyanite sample was received from M/s. Indian Copper Corporation for producing a concentrate analysing 60% Al₂O₃. The sample analysed 34.6% Al₂O₃.

Mineralogical examination of the sample indicated presence of Kyanite and small amounts of sillimanite. Gangue was composed of mica, quartz and minor amounts of rutile.

Humphrey's spiral tests and tabling tests at —48 mesh produced concentrates assaying 38.75% Al₂O₃ with 55.5% Al₂O₃ distribution and 23.5% Al₂O₃ with 57.4% Al₂O₃ distribution in them.

Flotation tests were conducted at 55% —200 mesh grind after desliming using 0.25 kg/tonne Lactic acid

and 0.75 kg/tonne of Sodium Sulphonate during roughing in acid circuit (pH=3.5) followed by three cleanings using 0.2 Kg each of Lactic acid and sulphonate in the first stage and 0.10 kg/tonne each of sulphonate in the subsequent stages. The final concentrate thus obtained analysed 60% Al_2O_3 with 39.5% Al_2O_3 distribution in it (Kyanite distribution equivalent is 55.6%).

Further increase in the reagent additions, tabling followed by flotation and cationic flotation tests did not show any remarkable improvement on the grade or recovery of Al_2O_3 . Attempts to recover Kyanite from the cleaner tails showed only 2-3% improvement while from the slimes were not successful.

6. Kyanite (Sample No. BT-4) from Lapsoburu Area—Bihar

Another sample was received from M/s. Indian Copper Corporation for the production of 60% Al_2O_3 grade concentrate. The original sample analysed as under.

<i>Constituent</i>	<i>Assay %</i>
Al_2O_3	25.40
SiO_2	68.29
Fe_2O_3	0.60
CaO	1.01
MgO	0.81
$\text{K}_2\text{O} + \text{Na}_2\text{O}$	1.17
LOI	0.40

Microscopic examination revealed only Kyanite to be the economic mineral while quartz and mica formed bulk of the sample. Minor amounts of rutile, apatite, tourmaline and hydroxides of iron were also observed. Kyanite was fairly liberated at 65 mesh size.

Humphrey's spiral test at 20 mesh produced a concentrate of 29.8% Al_2O_3 grade with 72.2% Al_2O_3 distribution while tabling at 48 mesh size produced a concentrate assaying 30.5% Al_2O_3 with 60.7% Al_2O_3 distribution.

Flotation tests with 50% —200 mesh deslimed feed with 0.3 kg/tonne of lactic acid and 1.0 kg/tonne of sulphonate in acid circuit (pH=3.5) followed by three cleanings produced a concentrate assaying 57.02% Al_2O_3 with 39.7% Al_2O_3 distribution. Similar flotation

tests with spiral concentrate yielded a concentrate analysing 57.44% Al_2O_3 with 36.2% Al_2O_3 distribution in it. Flotation tests with regrinding and cleaning did not improve the grade.

7. Kyanite from Sirbali Mines

The sample was received from M/s. S. Lal & Co., Calcutta; for beneficiation studies to produce refractory grade concentrate. The sample consisted of 50 mm lumps to fines and analysed as follows ;—

<i>Constituent</i>	<i>Assay %</i>
Al_2O_3	46.30
SiO_2	46.37
TiO_2	1.05
MgO	0.63
CaO	0.65
Fe_2O_3	2.14
$\text{Na}_2\text{O} + \text{K}_2\text{O}$	1.12
LOI	2.16

Examination of the sample under microscope indicated the presence of massive and foliated varieties of kyanite. Gangue were chiefly composed of quartz followed by muscovite and rutile. Minor amounts of sillimanite, magnetite and goethite were also observed. Kyanite was liberated from the gangue at 65 to 100 mesh size.

Tabling tests with sized 48 mesh feed produced a combined (coarse + fine) concentrate analysing 54.09% Al_2O_3 with 61.8% recovery, whereas with 100 mesh feed, the concentrate analysed 55.3% Al_2O_3 with 62.0% recovery.

Tests with 48 mesh feed in Humphrey's spiral yielded a concentrate of 50.9% Al_2O_3 grade with 71.5% recovery. Examination of the concentrate under microscope indicated that most of the mica was eliminated but still contained quartz.

Flotation tests with 36.5% —200 mesh grind employing lactic acid and petroleum sulphonate after two cleanings produced a concentrate analysing 56.8% Al_2O_3 with 59.2% recovery.

The sample was ground to pass 65 mesh screen and preconcentrated in a Humphrey's spiral. The spiral concentrate was further ground and then treated in a Fagergreen cell followed by two cleanings. The

concentrate thus produced analysed 60.1% Al_2O_3 with 57.6% recovery.

E. Andhra Pradesh Kyanite

About 250 kg. of kyanite sample from Khamam area in A.P. ranging in size from 7.5 mm to fines was received from M/s. Lal Traders & Agencies (P) Ltd. The sample had the following chemical analysis:

Constituent	Assay %
Al_2O_3	25.40
SiO_2	62.70
Fe_2O_3	8.25
CaO	0.12
MgO	0.55
TiO_2	0.01
K_2O	1.42
LOI	0.75
Na_2O	Trace.

Mineralogical examination of the sample revealed the presence of Kyanite followed by the gangue minerals like quartz, mica and garnet. Minor amounts of sillimanite, graphite, and andalusite, chlorite, apatite etc. were also present.

Tabling tests at 35 mesh liberation size after desliming yielded a concentrate assaying 27.5% Al_2O_3 with 74.4% Al_2O_3 distribution in it. Flotation tests with table concentrate using 0.5 kg/tonne H_2SO_4 (pH 3.0 to 3.5), 0.25 kg/tonne Lactic acid and 0.7 kg/tonne of sodium sulphonate followed by two cleanings with 0.15 kg/tonne of lactic acid in each stage produced a concentrate assaying 47.85% Al_2O_3 with an over all Al_2O_3 distribution of 53.8% in it.

High intensity magnetic separation of the concentrate followed by flotation of the non-magnetic fraction with two cleanings as mentioned earlier yielded a concentrate assaying 60% Al_2O_3 with 51.0% Al_2O_3 distribution in it.

The Summarised test results are given in Table 4.4.

TABLE 4.4 SUMMARY OF RESULTS OF BENEFICIATION OF KYANITE

State & Locality	% ROM Al_2O_3 Assay	Beneficiation Method	Conc. Al_2O_3 % Assay %	Conc. Recovery % Al_2O_3 %	Remarks
(1)	(2)	(7)	(4)	(5)	(6)
Maharashtra					
Dahagaon (1)	40.10	Flotation of gangue followed by mineral with cleanings	57.5	14.5	
Dahagaon (2)	38.4	"	59.6	42.5	
Dahagaon (3)	49.03	Humphrey's spiral followed by flotation and cleanings.	61.1	67.8	
Karnataka					
Mavinkere	64.09	Tabling at 35 mesh	72.76	—	Attempts to improve P.C.E. Value upto 1820°C
Orissa					
Megarmohan Mine	51.6	Flotation followed by two cleanings	60.8	67.3	
Pallahara Area					
Bihar					
Badia	45.34	Flotation with 3 cleanings	60.23	78.5	
Singhpura	51.23	Flotation followed by cleanings	61.1	82.7	Longer roughing time.
Rajkharswan	54.90	Hydrosizing & flotation of the fine sands only & mixed with untreated coarse sand.	60.4	75.9	

TABLE 4.4 SUMMARY OF RESULTS OF BENEFICIATION OF KYANITE (Contd.)

State & Locality	% ROM Al ₂ O ₃ Assay	Beneficiation Method	Conc. Al ₂ O ₃ % Assay %	Conc. Recovery % Al ₂ O ₃ %	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
Amda-Lapsu	38.2	Flotation with rejection of fines	60.4	48.8	
Sirbali Mines	46.8	Preconcentration on Humphreys spiral followed by grinding, flotation & 2 cleanings	60.1	57.6	
Lapsoburu-Bihar (BT/3)-HCL	34.6	Spiralling at 48 mesh Tabling at 48 mesh	38.75 39.5	55.5 57.4	
		3 cleanings	60.0	39.5	
Lapsoburu-Bihar (BT/4)-HCL	25.4 Al ₂ O ₃ 68.29 SiO ₂	Spiralling at 20 mesh Tabling at 48 mesh	29.8 30.5	72.2 60.7	
		Flotation with sulphonate PH = 3.5	57.02	39.7	
Andhra Pradesh					
Kyanite from Khamam	Al ₂ O ₃ 25.4 SiO ₂ 62.7 Fe ₂ O ₃ 8.25	Tabling at 35 mesh after desliming	27.5	74.4	
		Flotation of Table Conc. with 0.5 kg/t. H ₂ SO ₄ (pH = 3-30)	47.85	53.8	
		High intensity magnetic sepn. of Table conc. followed by flotation with 2 cleanings	60.0	51.0	

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