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Preconcentration and Heavy Minerals Separation Studies with Low Grade Beach Sand Sample from Narsapur Coast, West Godavari District, Andhra Pradesh

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Abstract

India is blessed with large reserves of strategic and economically important heavy minerals such as Ilmenite, Rutile, Leucoxene, Zircon, Monazite, Garnet and Sillimanite.

These deposits are mostly located in the coastal stretches of peninsular India covering states of Orissa, Andhra pradesh, Tamil nadu, Kerala and Maharastra.

Presently in India, the working beach sand processing plants of IREL and KMML are operating on rich grade deposits, whereas the placer deposits in Australia, Brazil, Mozambique and Kenya are commercially exploiting beach sand deposits with only about 4% of Ilmenite, that too in a source range of about 4 to 25% of heavy minerals.

Inspite of the country holding a dominant position in the world as regards to resources, its share in the world production is insignificant. Therefore it is essential to exploit the lean grade beach sand deposits in order to boost country's production of heavy minerals.

An attempt was made to pre-concentrate and separate heavy minerals from one such lean grade beach sand sample from West Godavari district of Andhra pradesh.

A composite sample of about 800 Kg was prepared by mixing the individual representative exploratory borehole samples collected over a length of about 14Km along the Narsapur Coast.Thus prepared sample was subjected to detailed characterization and Beneficiation studies.

The sample was found to contain about 15% Heavy minerals with about 10% of Ilmenite, 3.2% Monazite, 1.6% Zircon, 0.09 % Rutile, 0.4% Garnet and less than 0.2% Sillimanite.

The pre-concentration and mineral separation studies revealed that it is possible to obtain concentrates of Ilmenite, Monazite, Zircon and Garnet with a weight recovery of about 5.7%, 6.9%, 0.8% and 0.2% respectively.

This paper discusses the details of unit operations used and the process route followed in the batch scale studies.

INTRODUCTION

Narsapur coast is located in the West Godavari Dist. of Andhra Pradesh. It is situated between the Vainateya Godavari in the North East and Upputeru in the Southwest.

Well developed dunal system consists of frontal, inner and rear dunes are seen in this coast where in the heavy minerals Illmenite, Rutile, Garnet, Zircon, Monazite, Sillimanite, are distributed. To assess the heavy mineral potentiality of the Narsapur coast, the client has carried out exploration in a grid interval. In total about 14 Km was explored and core barrel drill samples were collected and combined to form a composite sample for characterization and heavy mineral separation studies.

CHARACTERISTICS OF THE SAMPLE

Physical Properties

The physical properties like specific gravity, bulk density and angle of repose were determined and the results are presented in Table-1

Table 1: Physical Properties of "As Received" Sample

Properteis	Value
Specicific gravity	2.89
Bulk density	1.449
Angle of repose	29^0 05'

Chemical Analysis of Major Oxides Present

The chemical analysis and size wise distribution of major oxides are presented in the Table-2 and Table-3.

Table 2: Chemical Composition of Major Oxides in the "As Received" Sample

Constituent	Assay percent
TiO_2	3.05
Fe_2O_3	4.33
FeO	1.51
SiO_2	69.89
Al_2O_3	7.95
ZrO_2	1.10
MnO	0.133
Cr_2O_3	0.071
V_2O_5	0.046
MgO	1.96
P_2O_5	0.094

Table 3: Size Wise Distribution of Major Oxides in the "As Received" Sample

Size		Wt%	Assay percent			Distribution percent		
Mesh	Micron		TiO_2	ZrO_2	SiO_2	TiO_2	ZrO_2	SiO_2
+35	+425	2.8	0.90	0.35	81.39	0.9	0.9	3.3
+48	+300	6.6	1.23	0.50	82.36	2.7	3.0	7.8
+65	+212	16.5	1.02	0.49	83.36	5.6	7.3	19.8
+100	+150	28.7	1.19	0.54	78.20	11.1	14.0	32.3
+150	+106	18.4	2.43	0.90	67.40	14.6	15.0	17.8
+200	+75	13.9	7.00	2.69	53.50	31.7	34.0	10.7
+250	+63	4.8	8.78	3.46	48.74	13.7	15.0	3.4
+325	+45	3.4	10.84	2.20	40.68	12.0	6.8	1.9
-325	-45	4.9	4.52	0.90	42.40	7.8	4.0	3.0
Head (Cal)		100.0	3.07	1.10	69.55	100.0	100.0	100.0
Head (Act)			3.05	1.10	69.89			

Sink & Float and Mineralogical Studies

The representative sample subjected to sink and float test using Bromoform as heavy liquid resulted 15.5 % heavy mineral content.

The heavy mineral content was subjected to mineralogical analysis by grain counting method wherein the influence of particle shape and size is ignored as of minor significance and simple counting of grains of different mineral species can be used to compute the volumetric percentages of each mineral species. Multiplying thus derived volume by its generally accepted specific gravity gives estimation of weight percentage distribution of different mineral species.

The mineralogical composition estimated by grain counting method is presented in the Table-4.

Table 4: Mineralogical Composition of "As Received" Sample

Mineral species	Percentage
Ilmenite	9.57
Monazite	3.2
Zircon	1.6
Rutile	0.09
Garnet	0.4
Sillimanite	<0.2
Quartz	85.39
Other	0.21

EXPERIMENTAL WORK

The experimental work was carried out in two stages first stage involving pre-concentration of heavy minerals by gravity separation technique and second stage involving separation tests by magnetic and electrostatic techniques.

Pre-Concentration Studies

About 800 Kg of composite sample was prepared by combining the individual bore hole samples collected during the exploration of the deposit was subjected to pre-concentration using Wilfley gravity table.

The "as received" sample was screened at 35 mesh to discard shells and coarser unwanted grains. Two stage pre-concentration was performed wherein the rougher tabling treating –35 mesh of "as received" sample and scavenger tabling treating the middling product obtained by the rougher tabling. Schematic diagram of flowsheet followed for pre-concentration with material balance is presented in the Process flowsheet-1.

The combined concentrate of rougher and scavenger tabling was found to be rich in Ilmenite, where as the middling was mixture of different heavy minerals. The tails of rougher and scavenger tabling was found to be mostly sand consisting of quartz and it was rejected.

Mineral Separation Studies

Separation of heavy minerals present in the pre-concentrate obtained from gravity concentration was tried by exploiting their differences in physical properties such as magnetic susceptibility, Electrical conductivity and specific gravity.

The scope of analysis of test products was limited to microscopic observation in order to assess the effectiveness of separation. However, model analysis and chemical analysis of all the final heavy mineral products were conducted.

Process Description

The heavy mineral separation studies were performed on the combined concentrate of both rougher and scavenger tabling (designated as concentrate-A) and separately on rougher middling product (designated as concentrate-B).

The results of mineral separation with combined concentrate is presented in process sheet-2, where as the results of heavy mineral separation with table middling and some products of process flow sheet-2 is presented in process flow sheet-3.

Based on the indicative separation tests it was observed that mineral separation efficiency was good on closely sized fractions. Therefore the pre-concentrate was subjected to dry screening using circular vibro screen in order to prepare closely sized fractions of –35+100#, -100+200# and –200#.

The individual size fractions were subjected to following separation techniques.

A] Low Intensity Magnetic Separator (LIMS)

Magnetic separation with three fractions of concentrate A and B was performed usind Box-Mag rapid disc type magnetic separator. Each fraction was reprocessed until all the highly susceptible Ilmenite grains were recovered as magnetic product and other minerals as Non-magnetic product.

B] High Tension Separator (H.T.Seaparator)

Magnetic products obtained from LIMS were subjected to Carpco H.T.Separator. Pure Ilmenite products were obtained as conductor and middling were recirculated until the maximum pure Ilmenite was recovered as conductor. Under microscopic observation conductor and middling fractions were found to be almost pure Ilmenite and Non- conductor fractions were found to be mixer of different minerals and categorized as intermediate product.

C] High Intensity Induced Roll Magnetic Separation (HIRMS)

LIMS non- mag products obtained from concentrate-A size fractions when viewed under microscope, it was observed that only +100 mesh fraction was found to contain most of garnet. Therefore only +100 mesh fraction was subjected to HIRMS and H.T separation to produce garnet concentrate. Considering the smaller quantities of +200 mesh and –200 mesh fractions, these were mixed with LIMS non-mag obtained from concentrate-B and processed further using HIRMS and Tabling. Here the magnetic intensity was first adjusted to recover maximum Monazite as magnetic product and Zircon, Quartz and Sillimanite as non-magnetic products. The magnetic product was again reprocessed at lower intensity to obtain cleaner Monazite concentrate.

D] Gravity Separation (Wilfley Table and Mozeley Mineral Separator)

HIRMS non-magnetic fractions were subjected to gravity separation to recover Zircon. The +100 mesh fraction was subjected to Mozley mineral separator using flat tray. The heavier concentrate was found to contain Zircon with little Monazite and Ilmenite. Lighter material was mostly Quartz with little Sillimanite was rejected. The heavier concentrate was again treated in HIRMS to upgrade Zircon content. In view of very less amount of Sillimanite in tailings no attempt was made to separate it.

CHARACTERIZATION OF FINAL PRODUCTS

All the final products were subjected to Chemical analysis, mineral modal analysis and size analysis. The results are presented in Table-5 to Table-7.

Table 5: Chemical Composition of Final Concentrates

A] Ilmenite Concentrate

Constituent	Assay Percent
TiO_2	44.20
Fe_2O_3	23.60
FeO	26.43
Cr_2O_3	0.16
P_2O_5	0.03
SiO_2	1.19

B] Zircon Concentrate

Constituent	Assay Percent
ZrO_2	38.8
Fe_2O_3	0.31
TiO_2	14.68
SiO_2	39.20

C] Garnet Concentrate

Constituent	Assay Percent
Al2O3	22.18
Fe2O3	18.92
TiO2	2.08
MnO	1.20
MgO	7.50
SiO2	35.51

Table 6: Modal Analysis of Final Concentrate

Concentrate	Wt%	Mineral composition in percentage					
		Ilmenite	Monazite	Zircon	Garnet	Rutile	Free state Quartz
Ilmenite	5.7	97.87	1.27	0.75	-	-	0.11
Monazite	6.9	15.72	70.97	6.81	2.70	0.11	2.70
Zircon	0.8	11.75	18.91	58.66	1.42	0.8	8.43
Garnet	0.2	16.33	4.86	3.57	73.05	-	0.70
Intermediate products	2.68	Admixture of different heavy minerals which could not be effectively separated					

Table 7: Size Distribution of Final Concentrates

Concentrate → Size		Ilmenite		Monazite		Zircon		Garnet	
Mesh	Micron	Wt%	Cumm wt% pass	Wt%	Cumm wt% pass	Wt%	Cumm wt% pass	Wt%	Cumm wt% pass
+35	+420	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0
+48	+300	0.0	100.0	0.3	98.7	0.0	100.0	3.2	96.8
+65	+212	0.6	99.4	2.0	97.7	0.0	100.0	25.4	71.4
+100	+150	5.3	94.1	14.5	83.2	0.2	99.8	71.4	-
+150	+106	26.4	67.7	37.4	45.8	29.3	70.5	0.0	
+200	+75	38.8	28.8	30.3	15.5	47.9	22.6	0.0	
+250	+63	16.9	12.0	9.9	5.6	16.0	6.6	0.0	
+325	+45	9.8	2.2	4.8	0.8	6.5	0.1	0.0	
-325	-45	2.2	-	0.8	-	0.10	-	0.0	
Total		100.0		100.0		100.0		100.0	

DISCUSSION ON TEST RESULTS

Recovery of Ilmenite by low intensity magnetic separation confirms its suitability as first unit operation in mineral separation plant followed by H.T separation to purify Ilmenite concentrate. During the LIMS test it was observed that inspite of reprocessing the non-mag product several times, some of Ilmenite grains remained unrecovered. Probably lower susceptibility of these Ilmenite grains may be one of the reasons and any attempt to increase the magnetic intensity to recover theses Ilmenite grains resulted into recovery of Monazite grains in to the mag. product.

H.T separation was found most suitable and effective for separating Ilmenite and Garnet from the concentrate obtained by LIMS. On reprocessing the middling fraction two to three times, it was observed that middling fraction was completely devoid of any garnet grains and therefore blended with conductor and was considered as Ilmenite concentrate.

High Intensity Induced Roll Magnetic Separation [HIRMS] using pinning principle was found effective for the separation of paramagnetic Monazite and Ilmenite grains from Non-magnetic Zircon, Sillimanite and Quartz grains.

Tabling was found to be effective in separating Zircon from Quartz and Sillimanite at coarser size range (–35+100) mesh whereas Mozley minerals concentrator was found suitable in recovering Zircon at finer size range (–100 mesh).

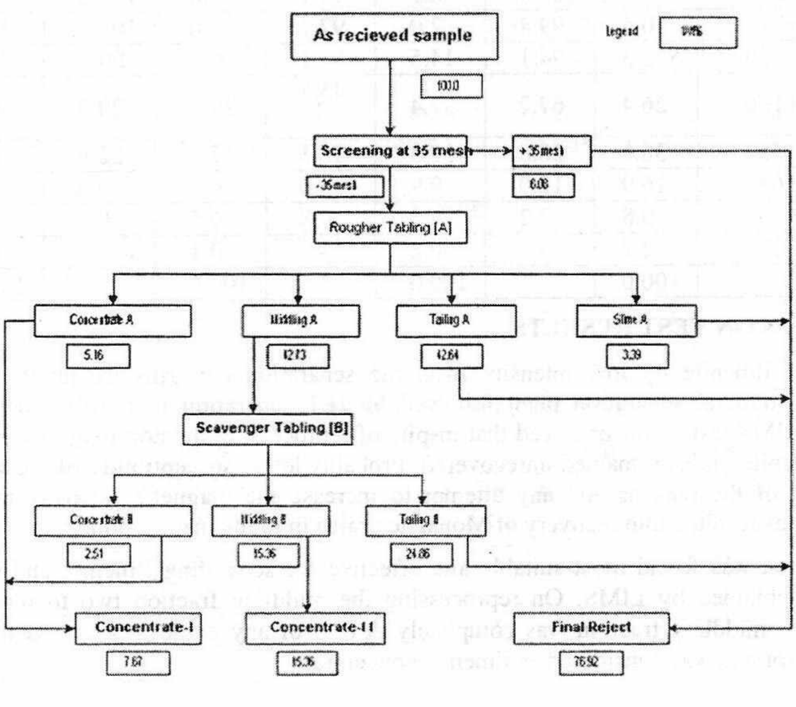
CONCLUSION

Based on the results of preconcentration and mineral separation studies following conclusions are drawn:

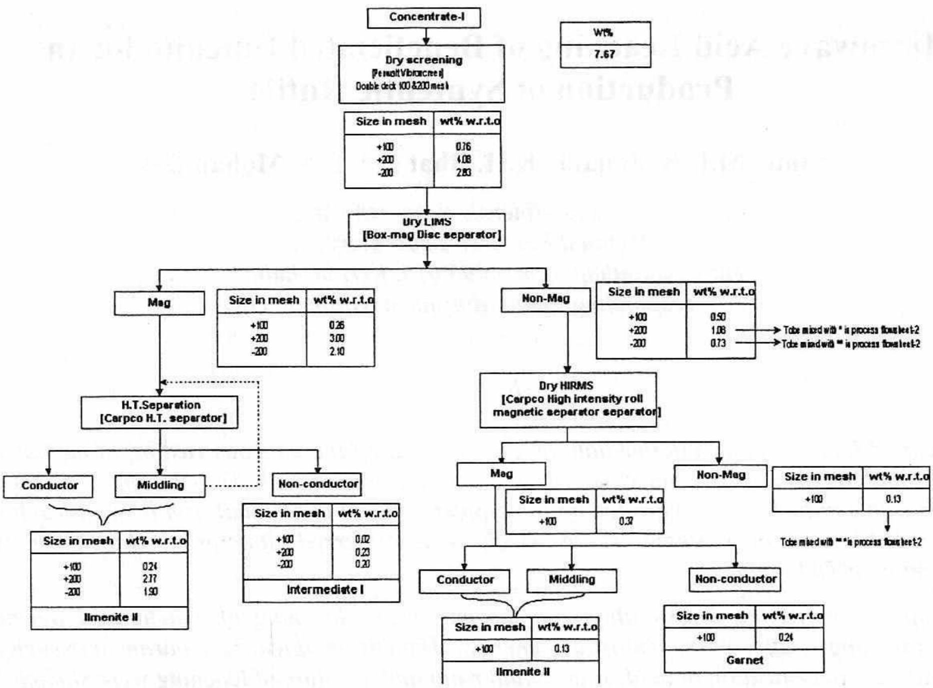
1) The overall percentage of total heavy minerals in the deposit is around 15% which is significantly less when compared to the existing beach sand deposits under exploitation in India.
2) The heavy minerals Ilmenite, Monazite, Zircon and Garnet are in the decreasing order of abundance and Rutile, Sillimianite are in traces.
3) Ilmenite is the major heavy mineral that could be recovered to the extent of 5.36% by weight with mineral purity of about 98%.
4) Monazite is the important radioactive mineral associated with other heavy minerals. The Monazite could be recovered with a yield of about 7 % with a purity of about 71%.
5) Zircon could be recovered to the extent of 0.65% by weight with mineral purity 58% and $ZrO2$ content about 39%.
6) Garnet was found to be concentrated in the coarse fraction (i.e. +100 mesh), which could be recovered to an extent of 0.21% by weight having mineral purity of 73%.
7) From the mineral separation studies it is recommended to classify the pre-concentrate into close size fractions before feeding to mineral separation equipments in order to achieve better separation and recovery.

Schematic Diagram of Flowsheet used for Pre-concentration Studies

Process flowsheet



Heavy mineral separation flowsheet and material balance with Concentrate-I **Process flowsheet-2**



Heavy mineral separation flowsheet and material balance with Concentrate-II **Process flowsheet-3**