Journal of Mining and Metallurgy, 48 A (1) (2012) 51 - 61

Journal of Mining and Metallurgy

CONCENTRATION PATTERN OF HEAVY MINERALS ALONG THE KONARK-RAMACHANDI COASTAL STRETCH AND ITS RECOVERY PROCESS FOR INDUSTRIAL APPLICATIONS

Sunita Routray[*#] and Raghupatruni Bhima Rao[**]

[*]C.V. Raman College of Engineering, Bhubaneswar 752054, India
[**]Aryan Institute of Engineering and Technology, Bhubaneswar 752050, India

(Received 26 April 2012; Accepted 30 August 2012)

Abstract

In this paper characterization studies are carried out on beach and dune sand samples collected from different locations of Konark-Ramachandi coastal stretch. Representative beach and dune sand samples were collected covering ~7 kilometres distance. Characterization studies reveals that d_{80} passing size for beach sand samples varies from 378 µm to 438 µm and for dune sand samples it varies from 440 µm to 482 µm. The THM content of beach sand samples vary from 16.8% to 18.2% and for dune sand THM varies from 9.9% to 12.3%. Total Magnetic Heavy Minerals (TMHM) percent of beach sands varies from 12.6% to 15.4% and for dune sand it varies from 6.5% to 9.2%. Beneficiation studies were carried out on composite bulk sample prepared from all beach and dune sand samples. The THM content of composite sample was found to be 16.7 %. Results of beneficiation studies show that ilmenite concentrate shows 6.0% yield with 99.4% grade. Garnet concentrate shows 4.8% yield with 94.0% grade. Sillimanite concentrate recovered with 2.7% of yield and 97.3% grade. The rutile concentrate obtained is 97.2 % grade with a yield of 0.11%. Zircon concentrate recovered shows yield of 0.13% with 98.0% grade.

Key words: *Beach sand, Dune sand, Heavy minerals, Ilmenite, Garnet, Rutile and Zircon.*

1. Introduction

Konark-Ramchandi coastal stretch is located in Puri district, Odisha, India (Lat.17°49’-22°34’N and Long.81°29’-87°29’E). The location map is given in Fig. 1. This coast is essentially alluvial, devoid of any rock exposures and consists of unsorted fine to medium grained, rounded to sub-rounded sand mixed in varying degrees with heavy (ilmenite rutile, sillimanite, garnet, zircon) and light minerals (quartz and feldspar). The area is characterised by a number of well-developed sand dunes. These sand dunes occupy considerable area along the coastal plain and are more or less parallel to the sea coast. Sand dunes are sign of ecological equilibrium between the powerful physical forces of the ocean waves, tide and current on one side and geological and/or natural resistance of the land on the other side. Geomorphologic

[#] ***Corresponding author:*** *sunitaroutray77@gmail.com*

features and mineral concentration of present study areas are shown in Fig. 2.

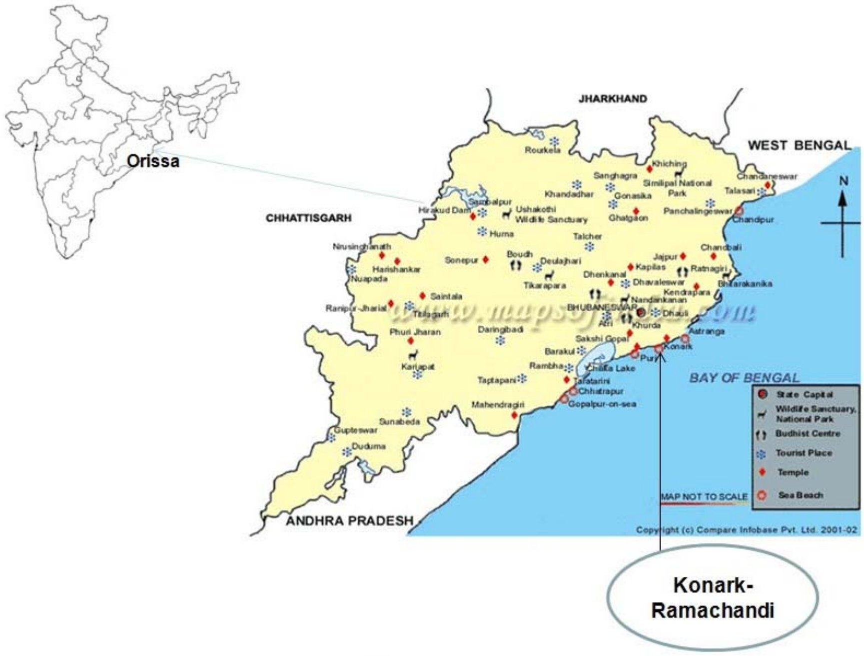

Figure 1. *Geological location for sampling areas*

Figure 2. *Typical topographical view of beach sand and dune sand along the coast at Konark-Ramachandi beach area, Orissa, India*

The heavy minerals concentrations such as garnet and ilmenite are shown in Figs 2a and 2b. The dune sand deposits of the coast are shown in Figs 2c and 2d. The main drainage of this area is the river Kusabhadra, which form the distributaries of the Mahanadi River. The Mahanadi originates from the hills of the Bastar Plateau in Raipur district. Chhattisgarh. Kusabhadra river branches off from the Kuakhai river, which is a distributary of the Mahanadi, at Balianta and flows in a south western direction towards Nimapara and Gop for 46–50 miles before sinking in to the Bay of Bengal near Ramachandi Temple, 15 miles east of Puri in the Puri District of Orissa. These beach and dune sands have variable range of heavy minerals like ilmenite, garnet, rutile, zircon and sillimanite.

Many authors have studied the heavy mineral deposits of Odisha, but no literature is found related to heavy mineral deposits of Konark-Ramachandi coast and their recovery [1-6]. In this paper an attempt has been made to study on the textural and concentration pattern of heavy minerals in beach and dune sands of Konark-Ramachandi coastal stretch, Odisha and the beneficiation process to recover individual heavy minerals.

2. Material and methods

Beach and dune sand samples were collected in a grid pattern at an equal interval of ~700 meters. Total ten beach and ten dune sand samples were collected covering ~ 7 kilometres distance. It may be noted that at each sample collection point itself, representative sample was prepared by coning and quartering method and packed in bags. Each representative sample weighed approximately 20 kg. All the samples were washed with fresh water before preconcentration studies as ten samples contains around 0.1 % of salt. Physical properties such as true density, total heavy mineral (THM) content and total magnetic heavy minerals (TMHH) content along with size analyses of all the samples were carried out using standard sieves. The d_{80} percent passing size of each grab sample has been calculated from the size analysis data. THM content was calculated by subjecting each sample to sink-float studies using bromoform (specific gravity 2.89). Magnetic separation studies were carried out using dry high intensity magnetic separator using Permroll magnetic separator, developed by ELB-YANTV and supplied by Ore Sorters (Australia) Pty., Ltd.

In order to study the response to recovery of total heavy minerals by using spiral, an attempt was made to prepare bulk (composite) feed sample from all the samples collected at different locations. Initially an attempt was made to reject lean tailings by using cleaner spirals. Subsequently, the tailings were subjected to scavenging spirals and recovered the final total heavy minerals. The THM was then subjected to different unit operations to recover individual heavy minerals.

3. Results and discussion

3.1. Textural and grain size distribution

The size analyses of beach sand bulk samples are shown in Table 1 and presented as histogram in Fig 3.

Table 1. *Size analyses of beach sand samples of Konark to Ramachandi coastal stretch (samples 1 to 10)*

Size, µm	1	2	3	4	5	6	7	8	9	10
	Weight, %									
-1000+600	5.9	5.2	3.9	3.4	6.4	3.3	3.8	4.2	6.0	2.8
-600+420	16.8	12.6	15.2	11.6	14.8	14.5	13.5	12.4	14.3	16.2
-420+300	24.3	22.5	19.6	18.6	17.5	20.9	18.5	20.3	18.1	27.2
-300+210	37.4	39.2	38.4	43.5	39.6	40.2	46.3	38.5	39.5	35.4
-210+150	7.5	11.9	9.5	11.4	12.6	12.3	12.8	13.2	12.3	12.5
-150+100	5.5	6.1	8.2	5.7	4.8	4.6	2.4	7.3	5.6	1.8
-100+75	1.2	1.5	2.7	3.1	2.8	3.1	1.5	3.4	2.2	1.8
-75+45	0.9	0.7	1.8	1.4	1.1	0.7	0.8	0.4	1.6	1.4
-45	0.5	0.3	0.7	1.3	0.4	0.4	0.4	0.3	0.4	0.9

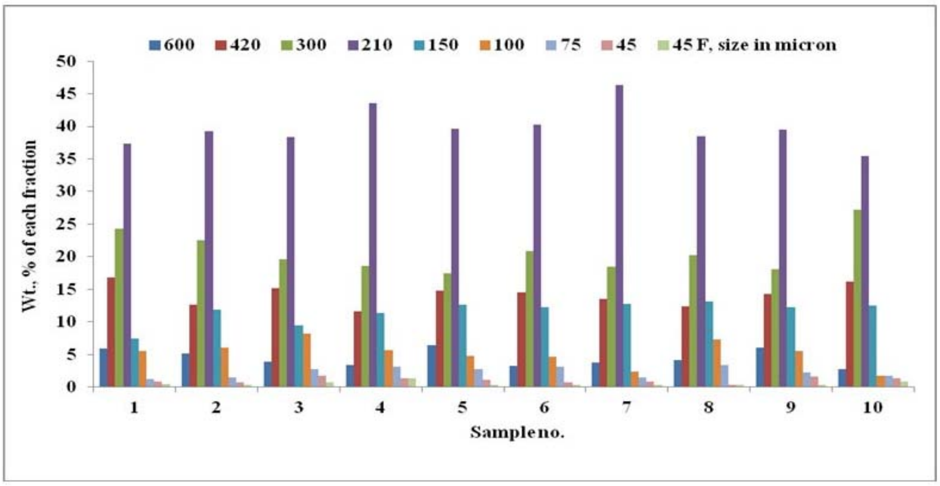

Figure 3. *Histogram showing size distribution of beach sand samples of Konark to Ramachandi coastal stretch (samples 1 to 10)*

Interestingly it is seen from the size analyses data for beach sand that with decreasing sieve aperture, from -1000 +600 µm , -600 +420 µm, -420 +300 µm and -300 +210 µm, the weight percent of the particles are gradually increasing for any given bulk sample (samples 1 to 10). Beyond -300 +210 µm size range the weight percent of the particles are decreasing and the end size fractions (-75 +45 µm and -45 µm) contain very less weight percent of particles. This can clearly be seen from the histogram graphs of these samples. The heights of the size frequency are significantly increasing from -1000 +600 µm to -300 +210 µm. The size frequency mode for all samples is seen at -300 +210 µm. In the present investigation, it is expected that there could be maximum light minerals occur at above +210 µm and maximum heavy minerals occurs at below 210 µm.

The size analyses of dune sand samples are shown in Table 2 and presented as histogram in Fig 4.

Table 2. *Size analyses of dune sand samples of Konark to Ramachandi coastal stretch (samples 1 to 10)*

Size, µm	1	2	3	4	5	6	7	8	9	10
	Weight, %									
-1000+600	10.5	7.6	8.2	6.8	9.1	5.9	6.3	8.4	9	7.3
-600+420	16.9	18.6	15.3	20.3	18.6	16.1	15.6	15.9	17.8	15
-420+300	21.4	17.6	15.8	18.2	20.3	22.6	19.2	21.6	15.2	20.6
-300+210	38.6	40.2	39.1	34.2	35.4	37.6	38.6	33.8	33.7	36.8
-210+150	8.8	9.6	12.7	12.4	13.2	11.7	13.5	14.8	15.2	14.1
-150+100	2.6	4.7	6.9	6.5	2.7	4.3	5.5	3.8	6.5	4.5
-100+75	0.6	1	0.9	1.2	0.4	0.9	0.6	0.8	1.8	0.8
-75+45	0.4	0.4	0.7	0.3	0.2	0.5	0.3	0.5	0.5	0.6
-45	0.2	0.3	0.4	0.1	0.1	0.2	0.2	0.4	0.4	0.3

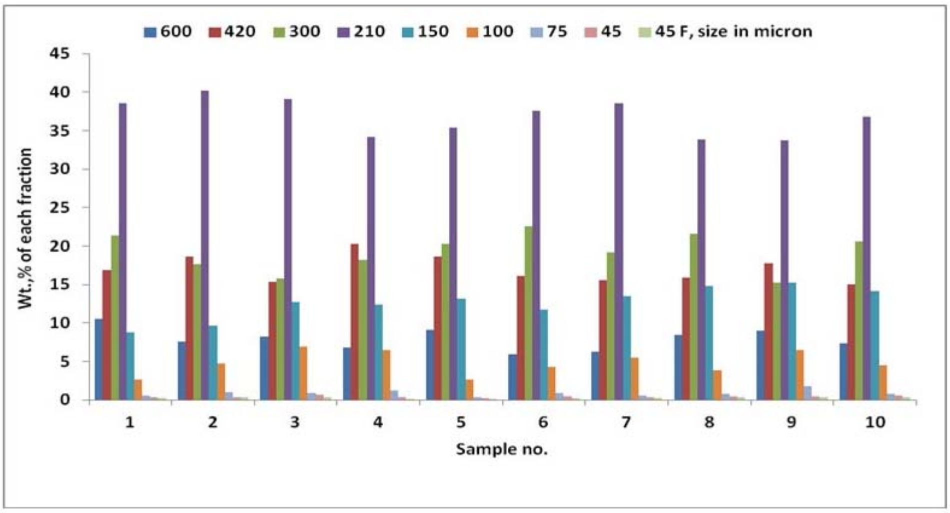

Figure 4. *Histogram showing size distribution of dune sand samples of Konark to Ramachandi coastal stretch (samples 1 to 10)*

The data indicate that the dune sand samples also show similar distribution pattern as that of beach sand samples as explained earlier. The weight percent of particles is increasing gradually from size fraction -1000 +600 µm upto -300 +210 µm and beyond -200 +150 µm the weight percent of particles is decreasing. The trend is same for all dune sand samples. The histogram in Fig 4 shows the size frequency mode for all samples which lies in the size range of -300 +210 µm.

The physical properties of beach and dune sand samples collected from Konark- Ramachandi beach are given in Tables 3 and 4.

Table 3. *Physical characters of beach sand samples of Konark to Ramachandi coastal stretch*

Sample	d_{80} passing size, µm	True density, g/cm^3	THM, %	TMHM, %
1	422	2.90	18.2	15.4
2	405	2.90	17.9	14.6
3	417	2.88	16.9	12.8
4	378	2.89	17.5	13.2
5	438	2.89	17.2	12.9
6	412	2.90	18.0	14.7
7	400	2.90	17.8	14.5
8	395	2.89	17.6	14.2
9	430	2.88	16.8	12.6
10	418	2.88	16.9	12.8

Table 4*. Physical characters of dune sand samples of Konark to Ramachandi coastal stretch*

Sample	d_{80} passing size, µm	True density, g/cm^3	THM, %	TMHM, %
1	482	2.79	11.5	8.3
2	470	2.78	10.8	7.2
3	458	2.78	11.0	7.5
4	470	2.80	11.8	8.9
5	478	2.79	11.6	8.4
6	440	2.79	11.3	8.2
7	440	2.77	10.5	7.1
8	460	2.76	9.9	6.5
9	478	2.80	12.3	9.2
10	450	2.78	10.7	7.3

The data presented in Tables 3 and 4 show that d_{80} passing size for beach sand samples varies from 378 µm to 438 µm and for dune sand samples it varies from 440 µm to 482 µm. This observation concludes that dune sand is coarser than beach sand.

The true density value for beach sand samples varies from 2.88 g/cm^3 to 2.9 g/cm^3 and for dune sands it varies from 2.76 g/cm^3 to 2.8 g/cm^3. The THM content of beach sand samples vary from 16.8% to 18.2% and for dune sand THM varies from 9.9% to 12.3%. It is observed that the true density and THM content of beach sand samples is higher than dune sand samples. The data also indicate that with increase in THM content, the true density value increases. This is because the heavy minerals possess high specific gravity value; hence with increase in amount of heavies the specific gravity or true density of that sample also increases.

It is also observed that with increase of particle size (d_{80} passing size) the true density of minerals is falling down. This observation can be expected as with increase in particle size, the total heavy mineral concentration decreases and the gangue minerals (quartz, feldspar etc.) whose specific gravity (2.6 g/cm^3) increases. Hence, the decrease in true density of the samples is justified. The Total Magnetic Heavy Minerals (TMHM) percent of beach sands varies from 12.6% to 15.4% and for dune sand it varies from 6.5% to 9.2%. The data indicates that magnetic minerals content is higher in beach sand than dune sand. This is expected, as the beach sand contain higher amount of THM and hence proportionately the TMHM content is also higher in beach sand.

The d_{80} passing size of beach and dune sand samples is correlated with physical properties such as true density, percentage of THM and percentage of TMHM of the samples of Konark-Ramachandi coastal stretch. The distribution pattern for true density of minerals present in the beach sand samples with respect to particle size are shown in Fig 5.

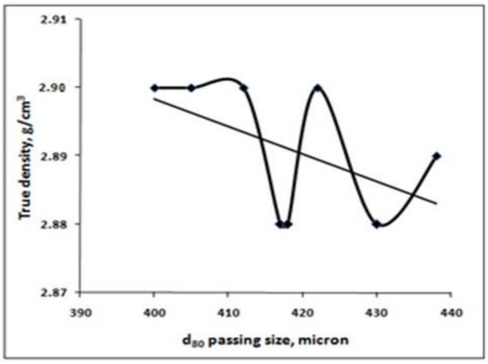

Figure 5. *d_{80} passing size vs. true density in beach sand samples*

It can clearly be seen from this figure that with increase of particle size, the true density of minerals is falling down for beach sand samples of all locations. This observation can be expected as with increasing particle size, the total heavy mineral concentration decreases and the gangue minerals (quartz, feldspar etc.) whose specific gravity (2.6 g/cm^3) increases. Hence, the decrease in true density of the samples is justified. Correlation of d_{80} passing size with true density of dune sand samples is shown in Fig 6.

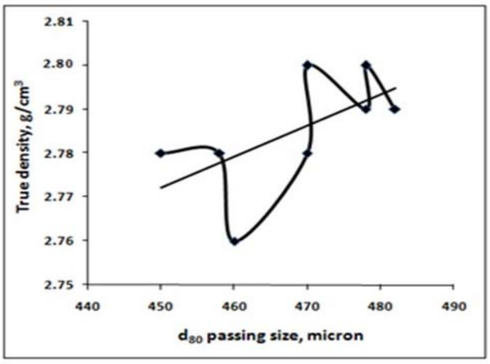

Figure 6. *d_{80} passing size vs. true density in dune sand samples*

It is interesting to know that the dune sand samples of Konark-Ramachandi coastal stretch show the opposite trend i.e. with increase in d_{80} passing size, true density is also increasing. It is seen in the field that concentration of coarse garnet is prominent, which may be reason to support the findings that with increase in d_{80} passing size, the true density of sample is also increasing. The distribution pattern of THM in beach sand samples with respect to d_{80} passing size of samples of study areas is shown in Fig 7.

As expected, the percentage of THM present in beach sand samples shows a decreasing trend with increase in d_{80}

passing size. This result is obvious because heavy minerals are generally concentrated in finer fractions. The distribution of THM in dune sand samples of three study areas is shown in Fig 8.

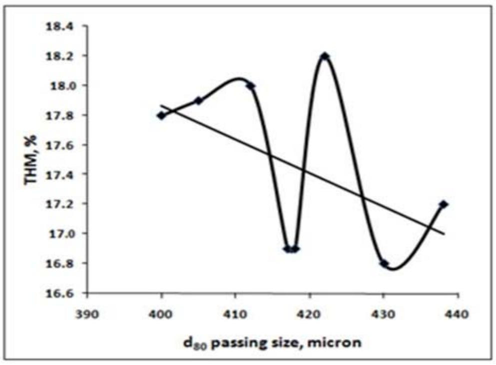

Figure 7. *d_{80} passing size vs. THM in beach sand samples*

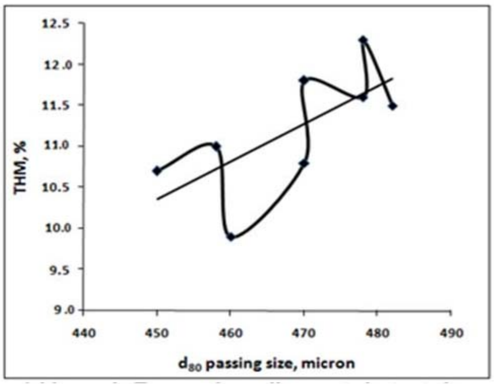

Figure 8. *d_{80} passing size vs. THM in dune sand samples*

It is again seen as interesting fact that for Konark-Ramachandi coastal stretch dune sand samples, the plot shows an opposite trend i.e. with increase in d_{80} passing size, the THM is also increasing. This is explained earlier that concentration of coarse garnet is prominent; whose specific gravity is 4.2 g/cm^3.

The distribution of Total Magnetic Heavy Minerals (TMHM) in beach sand samples is shown in Fig 9.

It is seen earlier that with increase in d_{80} passing size, the percentage of TMHM is decreasing. It is because the magnetic heavy minerals are generally concentrated in finer fractions. The distribution of TMHM in dune sand samples is shown in Fig 10.

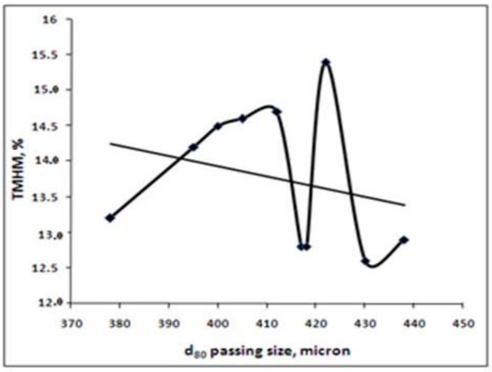

Figure 9. *d_{80} passing size vs. TMHM in beach sand samples*

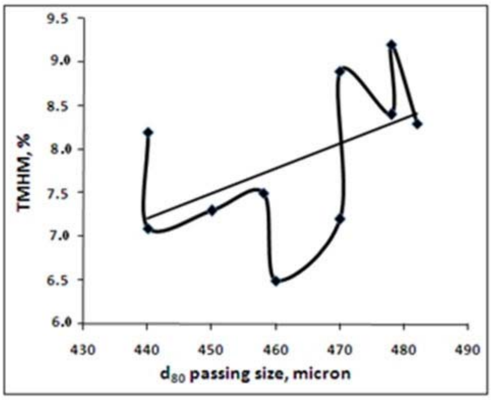

Figure 10. *d_{80} passing size vs. TMHM in dune sand samples*

Konark-Ramachandi coastal stretch samples show an opposite trend in the plot, as the magnetic mineral, garnet which is coarser in some of the samples.

3.2. Beneficiation studies to recover total heavy minerals

The physical properties of composite bulk sand sample are given in Table 5.

Table 5. *Physical properties of composite bulk sample*

Properties details	Konark- Ramachandi
Bulk density, g/cm^3	1.7
True density, g/cm^3	2.85
Porosity, %	41.5
Angle of repose, º	32.6
d_{80} passing size, µm	430
Total Heavy Minerals (THM) ,%	16.70
Total Magnetic Heavy Minerals (TMHM), %	12.74
Total Non-Magnetic Heavy Minerals (TNHM), %	3.96
Very Heavy Non magnetic Minerals (VHNM > 3.3g/cm^3), %	0.63
Light Heavy Non magnetic Minerals (LHNM < 3.3g/cm^3), %	3.33

The data indicate that the d_{80} passing size of the bulk feed sample is 430µm and the total heavy mineral content is 16.7%. The true density of the sample is 2.85 g/cm^3. The modal analysis of the total heavy minerals of the bulk sample shown in Fig.11 indicate that the sample contain 44.1% ilmenite, 31.5% garnet, 19.9% sillimanite, 0.96% zircon, 0.9% rutile, 0.66% monazite and 1.92% other minerals.

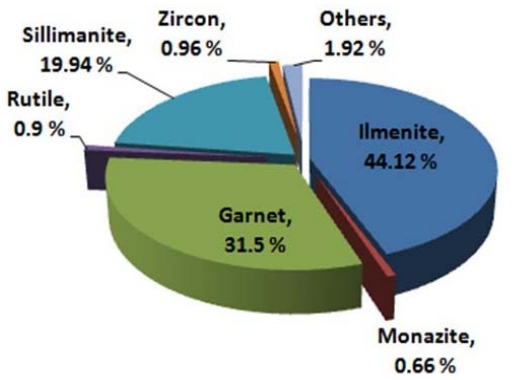

Figure 11. *Modal analyses of THM of composite samples*

The results of beneficiation studies are shown in Figure 12.

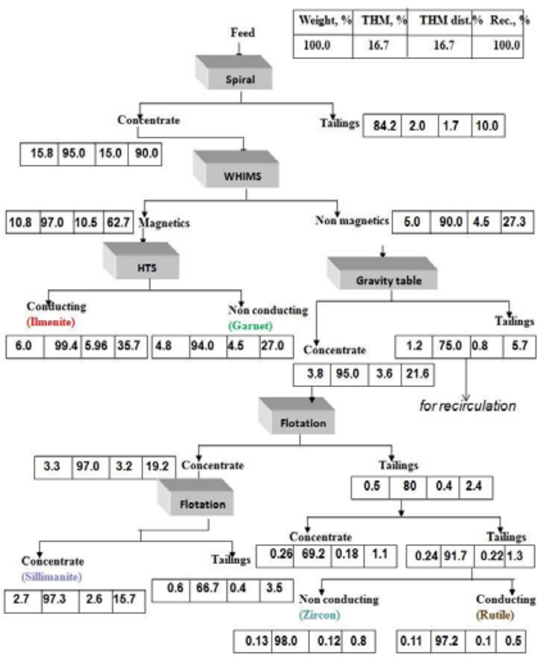

Figure 12. *Flowsheet with material balance to recover individual heavy minerals from Konark-Ramachandi bulk composite sample*

The spiral concentrate obtained after number of spiral operation shows a yield of 15.8 %, grade 95% with a recovery of 90%. Ilmenite concentrate recovered from total heavy minerals using different unit operations such as WHIMS and HTS shows 6.0% yield with 99.4% grade. Garnet concentrate recovered from total heavy minerals shows 4.8% yield with 94.0% grade. Sillimanite concentrate recovered by flotation process is with 2.7% of yield and 97.3% grade. The rutile concentrate obtained from total heavy minerals is 97.2 % grade with a yield of 0.11%. Zircon concentrate recovered in the non conducting fraction of HTS shows yield of 0.13% with 98.0% grade.

4. Conclusions

The following conclusions are drawn from the characterization and beneficiation studies of Konark-Ramachandi composite bulk sample:

- The true density of beach sand samples decreases with increase in d80 passing size, whereas dune sand samples show opposite behaviour, because it contains coarse garnet heavy minerals.
- The THM percent of beach sand samples decreases with increase in d80 passing size but the dune sand samples show opposite behavior
- The Konark-Ramachandi composite bulk sample contains 16.7% THM.
- The mineralogical modal analysis of THM of Konark-Ramachandi composite bulk sample shows that it contains 44.12% ilmenite, 31.5% garnet, 19.94% sillimanite, 0.96% zircon, 0.9% rutile, 0.66% monazite and 1.92% of other minerals.
- Ilmenite concentrate recovered from total heavy minerals using different unit operations such as WHIMS and HTS shows 6.0% yield with 99.4% grade and 35.7% THM recovery.
- Garnet concentrate recovered from total heavy minerals using different unit operations such as WHIMS and HTS shows 4.5% yield with 94.0% grade and 27% THM recovery.
- Sillimanite concentrate recovered by flotation process is with 2.7% of yield and 97.3% grade and 15.7% THM recovery.
- Zircon concentrate recovered in the non conducting fraction of HTS shows yield of 0.13% with 98.0% grade and 0.8% THM recovery.
- The rutile concentrate obtained from total heavy minerals is 97.2 % grade with a yield of 0.11% and 0.5% THM recovery.

5. Acknowledgement

The authors are thankful to the Director, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, for giving permission to carry out this research work. One of the authors, Ms. Sunita Routray is thankful to CSIR for granting SRF.

6. References

[1] A.K. Mohanty, S.K. Das, K.V. Van, D. Sengupta, S.K. Saha, Radiogenic heavy minerals in Chhatrapur beach placer deposit of Orissa, South-eastern coast of India, Journal of Radioanalytical and Nuclear Chemistry, 258 (2) (2003), 383-389.

[2] A.K. Mohanty, V. Vijayan, D. Sengupta, S.K. Das, S.K. Saha,

Geochemical characteristics of ilmenite sands of Chhatrapur beach placer deposit of Orissa, India, International Journal of PIXE, 13 (3/4) (2003), 121-131.

[3] A.K. Mohanty, D. Sengupta, S.K. Das, S.K. Saha, K.V. Van, Natural radioactivity and radiation exposure in the high background area at Chhatrapur beach placer deposit of Orissa, International Journal of Radioactivity, 75 (1) (2004), 15-33.

[4] R.K. Satapathy, S. Goswami, Mineral potential of Orissa state: A Kaleidoscopic Review – Orissa Review, May, (2006), 1-14.

[5] C. Satpathy, S. Routray, D. Srinivas Rao, Heavy mineral recovery from beach and dune sands of Ganjam coast, Orissa, India, World of Metallurgy – Erzmetall, 63 (1), (2010), 5-13.

[6] P. Behera, Heavy minerals in beach sands of Gopalpur and Paradeep along Orissa coast line, East coast of India", Indian Journal of Marine Sciences, 32 (2), (2003), 172-174.

[7] T. Laxmi, P. Nishad, K.E. Jayadevan, R. Bhima Rao, Textural and concentration pattern of heavy minerals in red sediments of badlands topography Bhimuni-patnam, Vishakhapatnam Dist., India, Journal of Mining and Metallurgy, 47 A (1), (2011), 75-91.