



Mining of beach sand heavy mineral deposits in India: challenges in Ground water and Coastal water management.

DR.A.SANTHARAM*, GOWTHAMI,V. , VINAY KUMAR** , TARACHAND,V.*****

, Visakhapatnam, Andhra Pradesh, INDIA

Email: asanthram33@gmail.com ,gowthamigeos@gmail.com

Abstract:

Beach sand placer deposits occur along the eastern and western coast of India, contain valuable economic minerals that are concentrated by weathering and beach process. The minerals of value in the mineral sands are predominantly ilmenite, rutile, zircon, garnet and silliminite. All these minerals are having potential industrial applications and export markets. There are several deposits which are being mined along the east coast and west coast.

Due to stringent environmental considerations and limitations in the lease area, mining, processing and reclamation and rehabilitation of the mined out areas is becoming a difficult task. Especially, the influence of ground water on mine workings and sea water intrusion into ground water regime need special attention during the operational cycle and reclamation phase. Therefore, it demands careful planning considering the hydro geological environment of the area.

The mining and processing of beach sand deposits need to be carried out in such a way to maintain the environmental sustainability without disturbing the ground water regime. The necessary mitigation measures include mining above the ground water table, without disturbing the ground water regime of the area, recycling of the process water, and development of natural sand dune topography to support local vegetation and overall landscaping of the area.

The paper deals with the best practices adopted in a beach sand mining and processing, by maintain the hydrological balance between mining, processing and mine reclamation. Case study of the mine is presented which include hydro geological investigations and selection of mining method, to carry out mining operations without disturbing the groundwater table and to maintain the water balance for optimum utilization of resources. Groundwater risks and mitigation measures were also discussed in detail.

*Regional Mining Geologist (Retd), Indian Bureau of Mines, Nagpur: email:asanthram33@gmail.com

** MS students (Geology), Dept. of Geology, Andhra University, Visakhapatnam (A.P.)

***ME student (Geo-technical Engineering), college of engineering, Andhra University, Visakhapatnam (A.P.)

Keyword: heavy minerals, beach sand mining, polymer injection, flocculants, material properties, slime recovery.

1. Introduction:

The Indian subcontinent on the southern part of Asia is having vast coast line along its eastern and western side. The favorable geological and geomorphologic features prevalent hydrodynamic process coupled with tropical climate network of rivers have resulted the formation of rich placer heavy minerals of commercial concentration along the eastern and western coast of India.

The minerals as placer deposits usually comprise of magnetite, ilmenite, rutile, and monazite. Magnetite,

silliminite and cassiterite, wolframite, gold and platinum etc. out of the various lean and potential deposits along the east coast of India, the deposits of Tamilnadu, Andhra Pradesh and Odissa state are of significance.

One of the important deposits of beach sand deposits located near Srikakulam, Andhra Pradesh, adjoin the Bay of Bengal. The deposits are having considerable strike extension and favorable working width for commercial exploitation.

The paper deals with the eco- friendly mining and mineral processing, separation technologies maintaining

the zero discharge ground water regime of the ecologically fragile area. The water balance is being maintained during the entire sequence of mining operations, without disturbing the ground water table.

1.1. Beach sand heavy minerals mining:

Usually, the raw sand in which the concentration of heavy minerals is observed contains 17 – 20 % of the heavy minerals such as Monazite, Ilmenite, Zircon, Rutile and Silliminite. These sands are being mined with the help of hydraulic excavators up to a mineralized depth of 8 m, without disturbing the ground water regime, which is lower than these formations.

The excavated raw sand is transported by trucks to the mineral processing plant for subsequent concentration of heavy minerals in wet upgradation plant. The wet upgraded plant is having different concentration processors such as cyclones, spiral and thickeners. The slurry containing heavy minerals is further processed with the help of spiral gravity classifiers in successive stages to produce a heavy mineral concentrate. Dry magnetic separators will further separate the individual minerals based on the magnetic susceptibility properties of minerals into their concentrates.

The output upgradation plant is 99% heavy minerals and is further beneficiated in mineral separation plant to produce mineral product of desired purity. The tailings(the waste material after processing the minerals, usually contain Quartz and clay materials is pumped back to the excavated portion of the mined out area for refilling and also to maintain the natural dune topography and contouring geology of the project area.

1.1.1. Formation of beach sand deposits:

Deposits are only formed when there is a very large enrichment of the heavy minerals. (Mineable) concentrations of relatively heavy or hard minerals which have accumulated as a result of physical processes are called *placer(s)* or *placer deposits*. Because many heavy minerals are opaque and darken the sediment when they reach large concentrations, the term *black sands* or *mineral sands*.

The heavy mineral deposits are located between Nagavali River in the SW and Vamsadhara River in the NE direction. The entire area is covered in Survey of India toposheet No.65N/6 and 74B/13(part). (Refer Fig.1.).A series of discontinuous hill ranges running NE – SW trend (Eastern Ghats) form the prominent geomorphological feature along the coast. The source rocks are Garnet-Silliminite –Graphic gneiss, Charnckite, Garnet-Biotite gneiss, and Garnetiferous-Quartzo-felspathic gneiss occupying the greater part of the Eastern Ghats. These rock types were disintegrated and altered during extensive weathering process as evidenced by Kaolinisation (clay forming process). The liberated fragments are transported by Nagavali River in

the south and Vamsadhara River in the North, which drain into Bay of Bengal. The thickness of heavy minerals sands depend on factors such as (a) slope of the coast line, (b) slope of the sea bed (c) velocity of waves and currents. (d) Wind direction, (e) proximity of Confluence River or streams.

The following description of the local geology indicates similar geo-environmental condition of heavy mineral sand distribution in the lease hold area. The area consists of three vertical geology columns;

- [1] An upper fine to medium grained homogeneous beach sand that is brown in colour and that has possibly been reworked and re-deposited by coastal wind and water action.
- [2] A coarse to fine grained homogeneous beach sand that is brown in colour and is possibly an alluvial sediment from the most recent deltaic pro-gradation.
- [3] Lagoonal grey clay (basement).
- [4] Red sand clay exposed towards the northern island side of the project area, which might have been derived from alteration of laterite.

The following geological domains which were defined percentages slimes (<63µm) as summarized in Table-1.

Table 1: Summary of domain depths

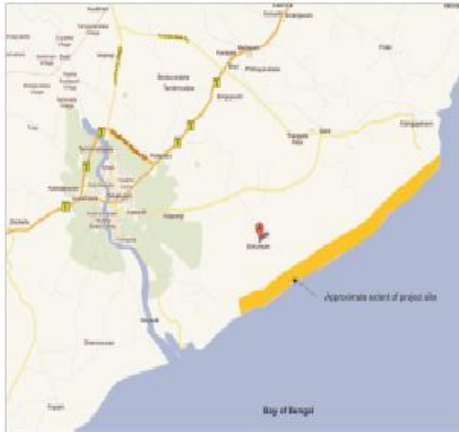
Litho units	Domain	Average thickness
Upper sand	Upper sand	4.12 m-6.4 m
Clayey sand Sandy clay	Lower sand	4.4m-5.3m
Total		8.52m-11.7m

The total reserves of the heavy minerals raw sand in Srikakulam mineral sand deposit at a cut off grade of 5% HM is estimated at 90 million tons with an average grade of about 25% heavy minerals. However considering occurrence of clay in the deposit, the reserve and grade estimates have been done for free flowing and clay upper and lower sand zone of high clay content.

1.1.2 Water Resource management

In the mining process fresh being used for mineral extraction in the PCP as well MSP plants. Mineral free sand from PCP will be pumped back in the form of slurry to the mined out pits along with the fresh water which will be about 30 to 40 % of total volume and is continuous daily process. Thus, the loose sand is filling the mined pits and pumped water percolating the sand and join with table. Some time water gets stagnated and will be recycled. It takes about 3 million tons to refill the mined out pit. Requirement of water for mining and ore dressing by the industry include the expansion project will be about 750 M³/Hr for 20 Hrs/Day totaling to 15000 cum/Day. The industry established an

infiltration gallery in Vamsadhara River bed near Gara village after obtaining permission from Government of Andhra Pradesh. At any stage, ground water is not extracted in the mining area for ore dressing.



2. Hydrology:

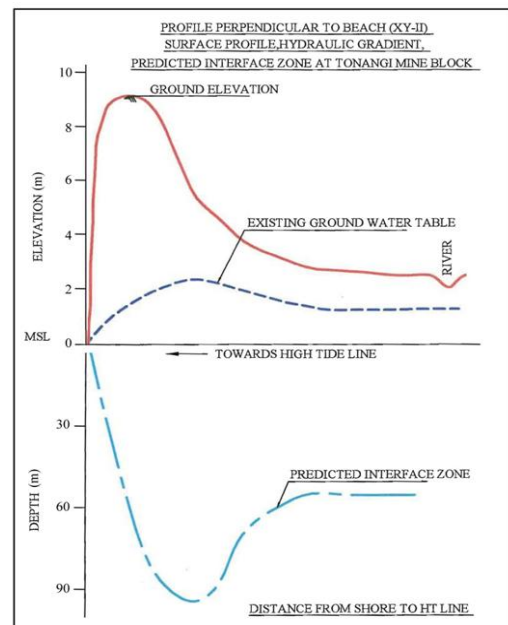
Two perennial rivers viz Nagavali and Vamsadhara entangle the area. Vamsadhara is flowing in the Northern part of the deposits while the Nagavali is flowing in the southern part. Vamsadhara merges with Bay of Bengal at South of Kalingapatnam. The back water of Vamsadhara is observed up to a maximum distance of 2.4 km from the high tide line (SOI topo sheet).



Apart from river Vamsadhara, the study area is also witnessed by another minor drainage stream named as Uppu Gedda which bifurcates the proposed mining deposits as Vatsavalasa and Tonangi and joins in Bay of Bengal at south of Kumaravanipeta. Uppu Gedda is generally dry and merely acting as a seasonal drainage stream. The width of the Vamsadhara River varies from 316 m to 1.1 km within the study area. River gauging has been conducted near Gara village during post monsoon and premonsoon period (November, 2011 to April, 2012).

3. Hydrogeological Investigations:

Hydrogeologically, the area can be grouped under recent alluvium sedimentary formation, comprising Paleozoic to Archean rock as basement. In the area occupied by alluvium coastal sand and clayey sand, ground water occurs during unconfined conditions. The water levels vary from 1.30m below ground level (bgl) to 9.51m (BGL) depending upon the ground elevation. The distance from the coast and level of ground water exploitation. With the intention of establishing the ground water contour map for the study area, about 36 wells are inventoried and the static water levels were measured. The locations of these wells are shown in Fig 5. The location of the measured wells are identified with GPS and given in Table-2. Well dimensions, depth to water table and source well information are listed in Table-3. From the data it is observed that the water levels are almost in same heights and maintain static flow where as it was marginally varying in the plateau. Although the measured wells are regularly used for domestic consumption there is no remarkable change in the water table, indicating sufficient yield from aquifer. This may be due to (a) continuous fresh water flow of Vamsadhara River, which recharges the flood plain aquifer which is exposed to the river bed and extending to the depth of 60 to 85m. (b) Extraction of ground water is less than the recharge quantity of ground water. The water table contours are presented in Fig 2.



3.1 perpendicular profiles to beach (XY-1 Figure 5):

It is evident from the profile that the sea coast is represented by elevated topography when compared to background landmass and a hill is encountered nearer to Gara village with a height of 69m. The ground water table exists at an average depth of 10 m BGL. But it is

relatively closer to the surface in the buffer zone depending upon the elevation. It appears that the ground water table approaches nearer to the surface as we move towards the Vamsadhara. It indicates the influent character of the river and the ground water is being recharged by Vamsadhara River. The complete stretch of the section falls under same aquifer, which is exposed to the river bed.

3.2 Perpendicular profile to beach (XY-II Figure 6):

It is apparent from the profile that the ground level at the sea coast is elevated to 10m and slowly dips to flatter topography of adjacent buffer zone landmass. Here the ground water table exists at an average depth of 6m (BGL) at the proposal mining. But it is relatively closer at average depth of 4m to the surface in the buffer zone depending upon the elevation; it appears from the section that the ground water table almost flattens as we move towards the river Vamsadhara. It indicated that (i) the aquifer is extending beyond the river and receives vertical percolation from river. (ii) the fresh water table enters in to the sea at Zero level table-4; chemical analysis of water samples collected from the study area

Table 2 Chemical Analysis of Water samples collected from the Study area

Parameters	Sample locations									
	1	2	3	4	5	6	7	8	9	10
pH	7.24	7.31	7.80	7.74	7.47	8.20	7.75	8.15	7.80	7.75
EC micro siemens/cm	2100	1800	1900	5200	3600	57000	150	2200	1890	6400
TDS mg/l	1370	1180	1250	3220	2320	34200	810	1450	1230	4100
Total hardness CaCO ₃ in mg/l	330	250	145	765	425	5840	290	150	320	1200
Calcium as Ca in mg/cl	72	42	40	152	76	336	76	24	48	192
Magnesium as Mg in mg/cl	36	35	11	94	57	1216	24	22	49	175
Sodium as Na in mg/l	250	270	370	620	610	10200	140	426	284	900
Potassium as K in mg/cl	150	50	3	380	30	450	20	2	10	30
Chlorides as Cl in mg/cl	341	163	284	951	671	19064	170	366	174	1644
Sulphates as So ₄ in mg/cl	130	252	132	444	346	1404	67	92	96	372
Bicarbonates as HCO ₃ in mg/cl	525	476	500	952	573	244	366	537	720	561
Suspended solids in mg/l	10	24	16	182	12	78	14	10	46	12
Density in gm/cc	1.001	1.001	1.001	1.003	1.002	1.035	1.001	1.002	1.001	1.004

1.1.2 Water Resource management:

The mining of beach sand minerals is totally different mining technology as compared to the other type of hard rock mining and processing. Water management is an important ongoing activity especially with the beach sand mining deposits, because it involves huge quantities of water for the wet beneficiation process, to liberate the minerals in the form of slurry by using different types of spiral classifiers and cyclones, which

work on the principal of gravity separation. after extracting the valuable minerals, the non mineralized sand in huge quantities will be pumped back to back in worked out areas, from which spent water will be recovered by making collecting ponds, from these collecting ponds the filtered water will be recycled for plant use. A novel method called “Polymer injection method” was developed recently to separate the water from the slimes, by using polymer additives which are cationic /anionic in nature. Before taking up the experiments, the material properties of slimes were tested shown in table - 3

Table 3 Index and Engineering Properties of Slime samples

S.No.	Index/ Engineering Property	Value
1	Specific Gravity	2.64
2	Grain Size Distribution	
i.	Gravel %	0
ii.	Sand %	8
iii.	Fines %	92
a.	Silt %	61
b.	Clay %	31
3	Plasticity Characteristics	
	Liquid Limit %	53
	Plastic Limited %	31
4	Compaction Characteristics	
i.	Optimum moisture content %	24
ii.	Maximum dry density g/cc	1.33
5	Unconfined Compressive strength at OMC & MOD (kN/m ²)	469
6	Undrained Cohesion (kN/m ²)	234.5

Based on the test results, the polymer additives which act as flocculants were studied by injecting a polymer prior to discharge to modify the structure of the tailings is a technique that was probably first undertaken within the last 5 or so years . Further investigation would be required in order to ensure that this concept could be suitable for rapidly consolidating fines and to determine (if necessary) whether the modify slimes can then be blended with the sand fraction to produce soil which can support vegetation or whether it might be feasible and preferable to blend the fraction before the discharge. It will however, still be necessary to improve the performance of the thickeners used to recover a large percentage of water from the fines in the plant before transport to the discharge as back fill. The tests followed by field trails indicated that it is possible to separate the water from slurry as demonstrated in the form of field trails.

3. Conclusions:

The water management is an integral part during the mining and processing of heavy mineral beach sands. Considerable quantities of water will be required to process the beach sands by wet concentration methods. Most of the beach sand heavy mineral deposits are located very close to sea shore around 500m distance. Environmental regulations will not allow disturbing the ground water lying 10 m below the surface. Therefore mining operations are restricted up to 8m depth. In most of the deposits water utilization and conservation practices are followed to minimize the effect of costal erosion and sea water-fresh water interface.

Polymer injection techniques were developed to separate the sea water from waste slurry and to recycle the water for plant use. These techniques are being practiced to sustainable growth of the mineral industry through best practices in environmental management.

4. References:

Journal Articles

- [1] Hydro geological studies in and around Srikakulam minerals Sand Deposits, Andhra Pradesh., (2005), Geo-Engineering Department, Andhra University.
- [2] Lower Sand Mining and Tailings Backfill operations (2011), Snowden, Australia.

Books

- [3] A.Santharam (2013) Report of investigation on effect of polymer injection techniques for dewatering the lower sand slimes, Trimex Sands Pvt. Ltd.
- [4] Bombrick.D.(2008) Impact of flocculant addition on tailings impoundment ACARP, Project C14064, October 2008.
- [5] Herald Eisner (2008) Heavy minerals Economic importance, BGR publishers, Germany.

Conference Proceedings

- [6] A.Santharam (2013) Geo technical considerations for the mining and dewatering slimes using polymer injection method, IX International Conference on heavy minerals. (accepted for publication), November 2013, Organised by South African Institute of Mining and Metallurgy, MEAI and Trimex, Visakhapatnam, India.