Heavy Mineral Sands in Kirinda Area, Deposit Characteristics and Extraction Potential

Fernando AKN, Perera EMNS, Saranga LS and *Vijitha AVP

Department of Earth Resources Engineering, University of Moratuwa, Sri lanka

*Corresponding author – vijitha@uom.lk

Abstract

Kirinda fishery harbour is dredged out periodically to pump out sand to maintain its depth. Sand samples (n= 38) were collected from the dredged-out sand pile covering all the regions and were analysed for mineralogy, particle size distribution (PSD) and microscopic observation. Mineralogical analysis via X-ray Diffraction (XRD) revealed positive availability of heavy minerals such as Ilmenite, Rutile and Zircon in different forms of compounds. As per the results of PSD test, more than 90% of the particles lay below 250 µm size. The highest percentage of the distribution fall in the range of 180 µm - 212µm. With the comparison of PSD graphs and geometrical parameters (mean, skewness, sorting, kurtosis) obtained from results, it can be concluded that the sand in the study area is well sorted. The X-Ray Fluorescent (XRF) test was carried out to find the enrichment ratio of heavy minerals. There was a considerable increment in the enrichment ratio of samples before and after Wilfley separation. But the percentage of heavy minerals in the samples is not up to upper continental crust limits of economically minable heavy minerals.

Keywords: Beach sand, Gravity separation, Ilmenite, Mineral processing

1   Introduction

Kirinda harbour is in Hambanthota district, southern province of Sri Lanka and surrounded by historical places like Sithulpawwa, Tissamaharamaya and Kataragama. Also close to Yala and Bundala National Parks as well.

The inlet of the Kirinda fisheries harbour is opened towards North Eastern direction as shown in the figure.2.

Longshore currents bring sandy material to Sri Lankan coast from eastern side and carry them towards western side of Sri Lanka [1]. Because of these longshore currents, sand tend to pileup inside Kirinda harbour. This has been an issue for the fishing activites carried out in the the area
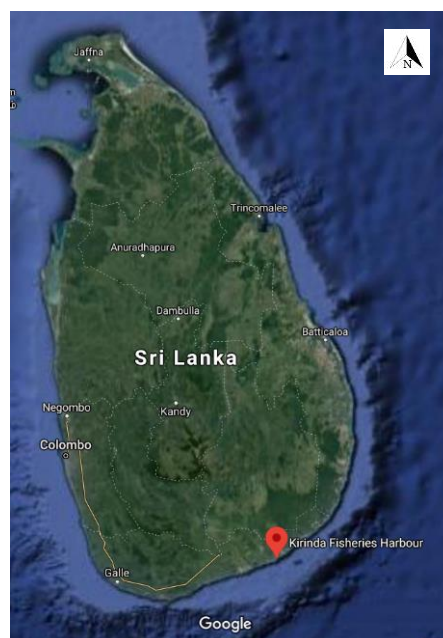
Figure. 1: Location of Kirinda fisheries harbour on Googlr map

and has led to additional expenses to pump out sand from the harbour in order to maintain required depth constant.[2] The pumped-out sand is being sold for construction purposes for a small profit with no value addition processes.

Two primary objectives are to be achieved through this study. First is to quantify the percentage of heavy mineral components and the other one is to find out an extraction method that optimizes the heavy mineral concentration of fine grain sands.

For further studies samples (n=38) were collected according to the grid pattern. The samples were mixed in order to prepare the composites for laboratory tests; sand density, particle size distribution (PSD), microscopic observation, mineralogical analysis via X-ray Diffraction (XRD) and quantitative analysis via X-ray Fluorescent (XRF).

Figure. 2: Plan view of Kirinda fisheries harbour on Google map

2   Methodology

The pumped-out sand is piled up near by the shore and has occupied in an area about 10500 m^2 to a height of about 5 m. (Figure. 3)

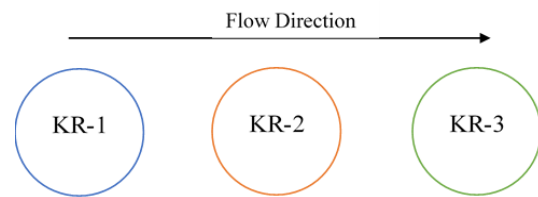Altogether 38 number of samples were collected from the study area. The

Figure 3: Composite samples with flow direction

coordinates of the sampling locations were reordered using Kandawala coordinate system.

Figure. 4: Sampling area on Google map

2.1   Sample collection procedure

Samples were collected using a shovel from about 0.5 m depth below the surface, because sand on the surface might be highly contaminated by the flow of water. They were gathered into sample bags and sealed, as soon as the samples were taken. Then those sample bags were numbered according to their positions and coordinates were recorded.

2.2 Preparation of composite samples & sampling method

Because of chute type sample splitter has less standard deviation of samples than cone & quarter and grab sampling[3], that method was adopted. Samples numbered from 32 to 46 were taken to prepare composite sample KR-1, samples numbered from 47 to 58 were taken to prepare composite sample KR-2 and samples numbered from 59 to 70 were taken to prepare composite sample KR-3 as for further studies.

2.3 Separation from Wilfley Table

1kg of each composite sample (KR-1, KR-2 & KR-3) was fed in to the Wilfley table and the concentrate was separated and kept for XRF and XRD analysis.

2.4 Particle size distribution

Samples were taken from each composite sample (KR-1, KR-2 & KR-3) and kept in the oven at 105^0C for 24 hours.
Then 500 g from each one was measured and the particle size distribution test was carried out.

2.5 Specific Gravity of The Sand Sample

Specific gravity of this sand was measured by volume displacement method. Three tests were conducted to find an average value.

2.6 Observations Through Elecronic Microscope

The first step is to identify the particles which are low grade or barren. Therefore, fractions resulted from particle size distribution test were observed through an electronic microscope and percentages of heavy fractions were calculated using particle counting method. Since, before feeding raw materials to the fine grain mineral separation instrument, heavy concentration can be increased.
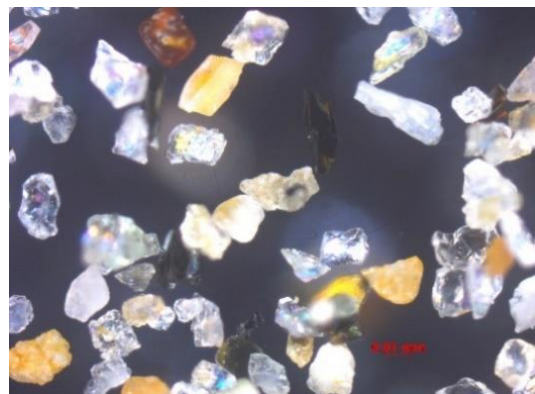

Figure. 5: Grains through optical microscope

2.7 Fine Grain Mineral Separation Instrument

The particle size of the sand is too smaller than the separation range of the Spiral and the Wilfley table Because of that a proper method is needed to upgrade the sample. So, an instrument was made, which follows a simple panning action[4]. Instrument allows grains to separate using gravitational force by giving a simple harmonic motion. Water sprays from the edges of the instrument. Curved portion holds the sample and that shape prevents spillover of slurry from sides. The angle of this instrument helps to remove excess water and the lighter portion of sand. The length and width of the instrument is 5ft and 2ft respectively, and those are fixed parameters. The frequency of simple harmonic motion, water flow rate and angle can be changed to optimize separation. (Figure. 6)

Figure. 6: Fine grain mineral separation instrument

2.8 XRD Analysis

A representative sample of the bulk volume was taken by splitting the sample using cone and quartering method.

Composite samples were then oven-dried at temperature of 105°C for 24 hours and then were ground using Temma mill to make the particle finer. These samples were fed to the XRD machinery (BRUKER D8 ADVANCE ECO X-ray diffractometer). Once the test was done heavy mineral were filtered using the XRD operating software.

2.9 XRF Analysis

Three samples were analyzed using XRF analysis. First sample was a raw sample that was directly taken from the beach deposit itself. Second sample was the heavey concentrate resulted from the Wilfley table and the third sample was the heavy concentrate resulted from the fine grain mineral separation instrument. Concetrates from Wilfley talble and fine grain mineral separation instrument were then oven-dried and ground using Temma mill same

as in XRD sample preparation and were fed to XRF machinery.

With the help of these results, the degree of optimization of concentration could be easily compared between Wilfley table and Fine grain mineral separation instrument.

3 Results and Discussion

3.1 Specific Gravity of The Sand Sample

The results obtained from specific gravity test are shown in the table below.

Table 1:Specific gravity test results

Test No.	Sample Weight [g]	Displaced Water Volume [ml]	Specific Gravity
1	100	36	2.78
2	150	55	2.73
3	200	72.5	2.76

Therefore, the average specific gravity is **2.75**.

3.2 Particle size distribution analysis

From particle size distribution analysis, following results were obtained. The same analysis was done twice to improve the accuracy of the test and the average was taken to analysis.

Table 2: Sieve analysis test results

Sieve Size [mm]	Cumulative Passing		
	KR-1	KR-2	KR-3
2	100.00%	100.00%	100.00%
1.4	99.85%	99.83%	99.98%
1.18	99.59%	99.73%	99.96%
0.85	99.18%	99.58%	99.94%
0.5	98.39%	99.14%	99.78%
0.425	95.17%	97.47%	99.28%
0.355	93.52%	96.43%	98.67%
0.25	90.29%	93.95%	97.44%

0.212	77.17%	78.69%	86.64%
0.18	60.44%	60.48%	71.09%
0.125	34.56%	32.38%	34.57%
0.106	7.55%	9.74%	9.77%
0.075	2.52%	4.33%	3.77%
Pan	0.11%	0.41%	0.40%

From the above results it was observed that more than 90% of the particles lie below 250μm. The highest percentage of size is retained in the fraction 180μm – 212μm. The grain size distribution is very much important for separation of heavy minerals.

3.2.1 Comparison of particle size distribution

Particles, size range from 400μm – 120μm are settled in the direction of natural slurry flow. Particle size lay in the range of 2mm – 400μm and 120μm – 75μm is same in all three samples (Figure.7) Particle size distribution of all three samples shows that the area is moderately well sorted.

3.3 XRF analysis

Table 3: XRF analysis test results

Element	Unit	Raw Sample	After Instrument	After Wilfley
SiO_2	%	67.52	47.44	63.52
TiO_2	%	0.44	5.2	1.76
Al_2O_3	%	11.77	13.6	12.33
Fe_2O_3	%	2.24	13.64	4.85
MnO	%	0.02	0.07	0.03
MgO	%	1.6	4.1	2.04
CaO	%	10.85	12.18	11.15
Na_2O	%	3	1.46	1.79
K_2O	%	2.46	1.83	2.3
P_2O_5	%	0.09	0.46	0.19
V	ppm	46	317	123
Cr	ppm	289	441	311
Ni	ppm	14	56	25
Cu	ppm	12	21	16
Zn	ppm	23	146	55
Ga	ppm	16	23	18
As	ppm	6	12	9
Rb	ppm	65	45	60
Sr	ppm	827	714	829
Y	ppm	12	61	25
Zr	ppm	270	2466	566
Nb	ppm	10	99	31
Mo	ppm	6	6	6
Cs	ppm	5	59	19
Ba	ppm	686	448	652
La	ppm	36	120	86
Ce	ppm	40	241	140
Pb	ppm	23	39	29
Th	ppm	10	72	34
U	ppm	12	11	12

There are background values for the major oxides which is in Upper Continental Crust (UCC) [5]. According to the figure 8 minerals like TiO_2, Fe_2O_3, P_2O_5 shows major increment of enrichment factor (1) after separation from the instrument.

From the above results it is clearly shown that the enrichment ratio (2) of heavy metals such as; TiO_2, Fe_2O_3, Niobium, etc. is higher in the Instrument separation than in the Wilfley table separation. It got almost 2.5 times larger value than in Wilfley table separation. Therefore, for the fine grain material which have same kind of particle size distribution can separate for heavy minerals better by the separation instrument than by the Wilfley table.

3.4 XRD results

Table 4: XRD analysis test results

Compound Name		Quality
Ilmenite, syn		Star (*)
Rutile, Niobian		Star (*)
Rutile		Star (*)
Zircon		Star (*)
Thallium copper zirconium sulphide		Star (*)
Thallium copper zirconium selenide		Star (*)

Holmium Aluminum Gallium Oxide	Star (*)
Spinel, syn	Star (*)
Strontium Aluminum Silicate	Star (*)
Monazite-(Nd), syn	Star (*)
Biotite-1M, syn	Star (*)
Corundum	Star (*)

As the results obtained from the XRD analysis, it can show that the elements which are presents in the XRF analysis is available in the form of different compounds.

4   Conclusions

This deposit is not economically viable, because heavy concentration is low compared to UCC major oxide percentage values and Rear Earth Elements are also not significant in the raw sample. Even though all major oxides except SiO_2 and CaO in raw sample are lower than UCC percentage values, the instrument has the ability to improve them to significant values.

5   Recommendations

XRF analysis should be carried out covering the entire deposit. Also further analysis should be done during both Monsoon and Off Monsoon seasons individually. More accurate results should be obtained using advanced instruments like ICPMS. Due to high concentration of $CaCO_3$ suitability of this sand for construction purposes must be investigated using correct and appropriate testing methods. Availability of Rear Earth Minerals should be investigated thoroughly by further advanced methods. Instrument should be developed further to optimize separation process.
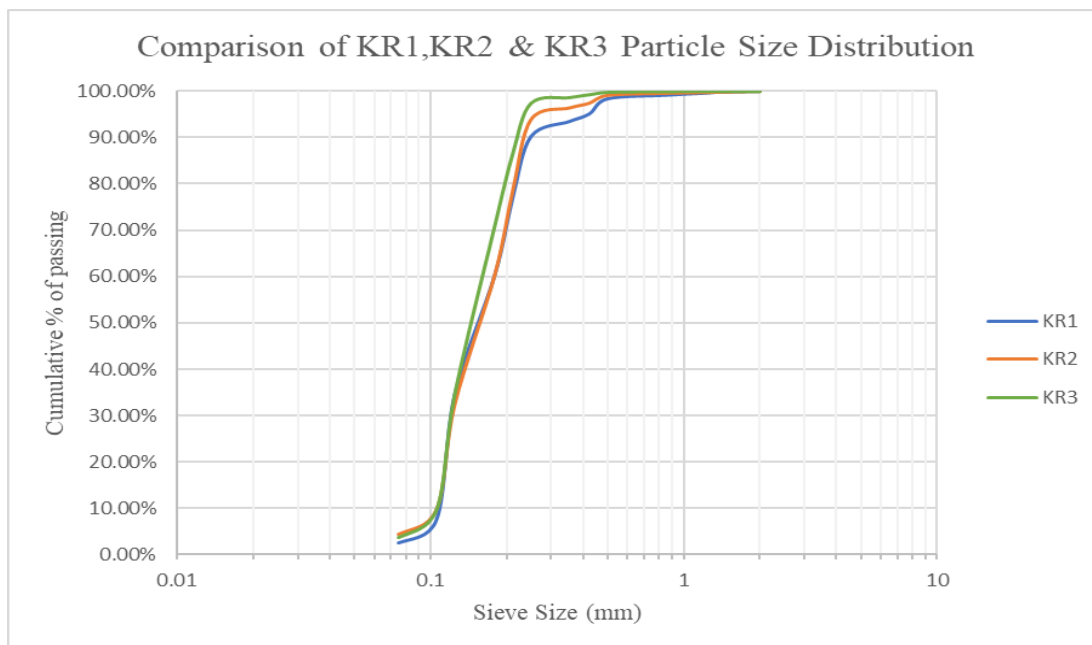

Figure. 7: Particle size distribution of KR-1, KR-2 & KR-3

$$Enrichment\ Factor = \frac{Percentage\ of\ major\ oxide\ in\ the\ sample}{Percentage\ of\ paricular\ oxide\ in\ UCC} \qquad (1)$$

$$Enrichment\ Ratio = \frac{Assay\ value\ (\%)\ of\ concentration\ material\ (c)}{Assay\ value\ (\%)feed\ material\ (f)} \qquad (2)$$
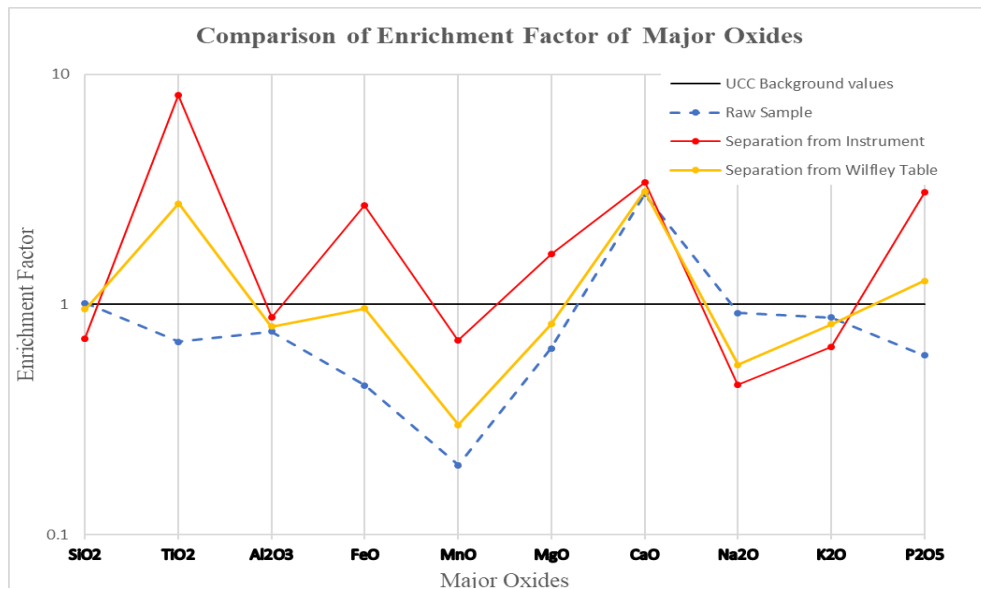

Figure. 8: Enrichment factor of maor oxides in KR-1 sample

6   References

[1]   Laknath, D. P. C. & Sasaki, J., (2010). *Study on sediment accumulation processes in Kirinda Fishery Harbour, Sri Lanka*. Volume 3, pp. 840-847.

[2] CORPORATION, C. F. H., (2020). *CEYLON FISHERY HARBOURS CORPORATION.* http://www.cfhc.gov.lk/Harbour_Kirinda.htm, Visited, 10th August 2020.

[3] Michigan Tech, (2009). *Michigan Tech.* https://www.google.com/url?client=internal-element-cse&cx=009927719687488248387:eqqgmubonta&q=http://www.chem.mtu.edu/chem_eng/faculty/kawatra/CM3820_2009_Sampling.pdf&sa=U&ved=2ahUKEwj-v-_MhaDsAhXEILcAHYZgBHgQFjAEegQIAhAC&usg=AOvVaw0RvL11sIM37TaQrP-tc9S6, Visited, 20th August 2020.

[4] Insmartsystems, n.d. *Insmart Systems.* https://www.insmartsystems.in/minerals/mineral-beneficiation-sub/gravity-separation/mineral-separator/, Visited, 20th August 2020.

[5] Rudnick, R. & G., (2003). Composition of the Continental Crust. *Treatise on Geochemistry,* Volume 3, pp. 1-64.