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Preconcentration of Placer Critical Minerals from Red Sand Dunes

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ABSTRACT

In the current research, it is proposed that the Vertical Shaft Kiln (VSK) separator, an innovative air classifier, be implemented before the introduction of samples into wet processing circuits such as scrubbing and spirals. This measure aims to mitigate environmental pollution in the downstream marine environment. The incorporation of an air classifier allows for the removal of undesirable slimes that contribute to pollution, which constitute 9.8% by weight, including 5.3% Light Heavy Minerals (LHM). These LHM are non-commercial gangue minerals, comprising pyroxenes and amphibole minerals, and can be eliminated prior to the wet processing stage. Consequently, this approach reduces water pollution downstream, decreases water usage, and enhances the economic viability of the plant.

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1. INTRODUCTION

On the one hand the demand for electronic units such as mobiles etc is increasing to satisfy the urgent need of advanced technology for mankind and on the other hand the scarcity of raw materials for production of advanced materials is decreasing, it is felt necessary to explore and recover the raw material which contain even lean and off grade ores also. Furthermore, as a result of water scarcity and pollution, the Indian mining sector intends to substitute certain wet-dry procedures with state-of-the-art cyclones or fluidized bed separators. These advanced cyclones serve as classifiers, with their design and functioning mirroring that of hydro-cyclones. Within the mining and mineral field, air cyclones play a crucial role in closed circuit dry grinding units by disrupting the dispersion of coarse and fine particles, and redirecting the coarse particles back into the system. However, it has no known use in separating heavy and light minerals and dust or slime or slit. Hence, any innovative design that fulfils the criteria concerning size distribution, dust retrieval, and extraction of valuable minerals from deposits is appropriate for implementation in the dry cyclone. The Vertical Shaft Kiln (VSK) separator represents an air classifier that combines static and dynamic separators, effectively meeting the aforementioned criteria. However, the property has been adopted by the international cement industry as well as some fertilizer industries. However, so far, the CSIR - Institute of Minerals and Materials Technology (CSIR IMMT) reported on a few experimental R&D studies for the beach sand industry and limestone industry (Bhima Rao, 2012; Bhima Rao and Das, 2008) and no further tests have been conducted on particle size distribution, concentration and dust / silt or slimes separation from sand dunes. IMMT, Bhubaneswar, has also done some scientific research on separation, which involves separation of fines or silt from Teri sands (Teri means red) in Tamil Nadu (Bhima Rao, 2007), Andhra Pradesh and Odisha by wet scrubbing which is a common method of removing red slimes or silt. These red sediments are being released during the monsoon and causing environmental pollution in the down streams such as rives and sea. A few researchers (Venu and Velmayil, 2021; Jayangondaperumal, 2014; Jayangondaperumal et al., 2012b,a; Perumal and Udayanapillai, 2019, 2020; Thrivikramji et al., 2008, Udayanapillai and Ganesamoorthy, 2013;

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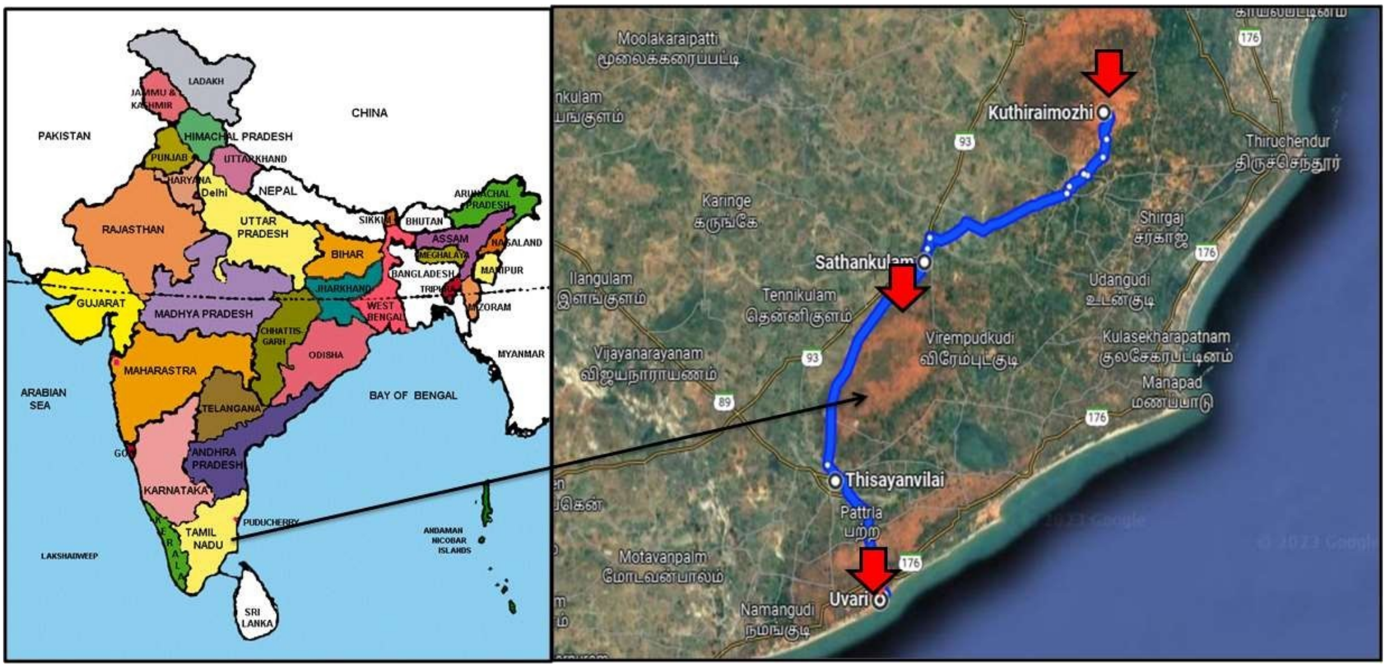

Fig. 1. Aeolian placer red sand dune samples collected from different locations.

Udayanapillai et al., 2016; Mir Azam Ali et al., 2001; Chandrasekharan and Murugan, 2001) studied the environment, nature of the red sediments, geology and geochemistry but not attempted for separation of sediments for industrialisation. The main objective of this project is to dry separation process using VSK separator an advanced air cyclone to reduce slimes (to the greatest extent possible) without losing the value of the slime.

2. MATERIALS AND METHODS

About two tons of Teri sand was procured from different locations (Fig. 1) of Tami Nadu for reduction of slimes by using dry cyclones (VSK). Characterization of teri sand was carried out by using size and size wise analysis of feed by wet and dry methods, estimation of slime contents by wet and dry methods, estimation of Total Heavy Minerals (THM) in sand and slimes, physical properties of feed and slimes (specific gravity, bulk density, angle of repose, moisture content etc), chemical analysis of slimes and determination of silt and clay content by XRD. VSK separator tests were carried out using variables such as effect of moisture content, effect of feed rate, effect of cage speed and effect of air rate. Data evaluation based on the feed characteristics, sink float tests, size analysis, assessing coarser fraction for quartz sand and heavy minerals, assessing slimes fraction for quartz sand and heavy minerals and design of operating parameters.

2.1. Studies on VSK separator

The VSK separator is a pilot plant, with model number SKS VS 10.4, was created and put into operation at IMMT, Bhubaneswar by M/s Humboldt Wedag India. This pilot plant was utilized in the current research on the separation of fines and heavy minerals, as depicted in Fig. 2. Initially, all experiments were conducted in a batch mode, with the model consistently connected to the feeder to ensure a steady aerodynamic environment. Samples for each change were collected every ten minutes. In the experimental design for different treatments, the operating variables such as cage wheel speed from 400 to 1200 rpm, fan (Hz) from 9 to 49 (airflow), humidity from 0.5 to 2%, and screw feeder speed control from 800 to 1200 rpm (Feed rate 1 kg/hour and 205 kg/hour) were maintained.

A comprehensive investigation was conducted on VSK separators, with a wheel cage speed of 1800 rpm, feeder speed of 1800 rpm, air speed of 49 (fan, Hz), and 0.5% humidity. Upon completion of the operation, the feed sample (weighing one ton) underwent processing through a coarser VSK separator to separate coarse and fine particles. The rougher coarse material was then further processed through a cleaner VSK separator to obtain clean coarse and fine material. Similarly, the rougher fine material underwent processing through a cleaner VSK separator to obtain cleaner coarse material. The fines

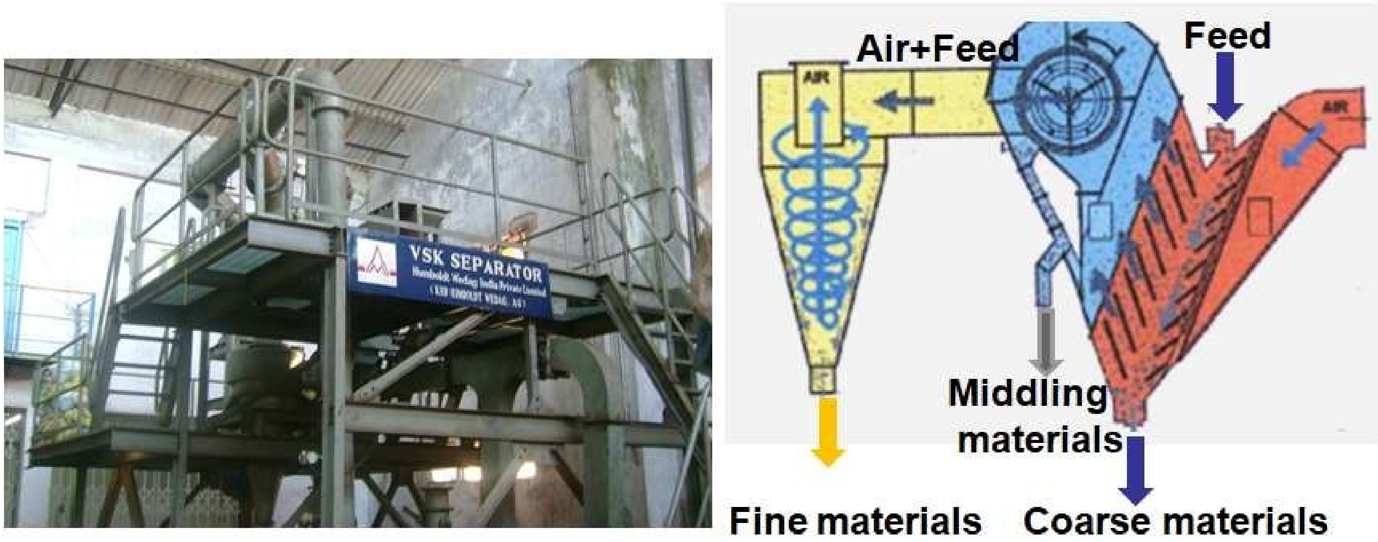

Fig. 2. The pilot plant of VSK separator [an advanced air cyclone] with functional sketch.

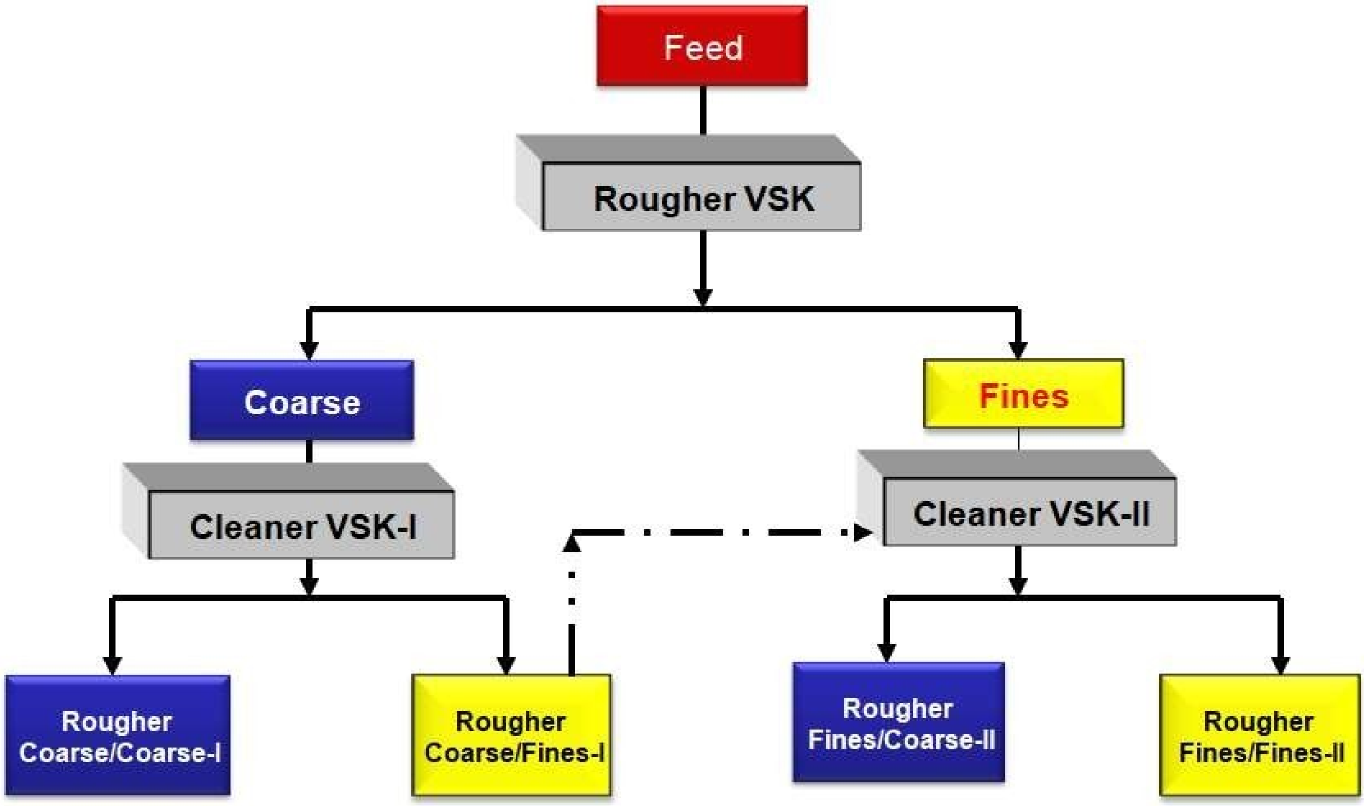

Fig. 3. The schematic flow sheet to recover coarse and fine materials by using VSK separator.

obtained from the rougher coarse and rougher fine materials were subjected to a scavenging VSK separator to separate rejectable fines and non-valuable minerals. The schematic flow sheet illustrating the recovery of coarse and fine materials using a VSK separator is presented in Fig. 3.

The performance of VSK is assessed independently from the physical characteristics of coarse and fine materials through dimensional measurement. The samples underwent dimensional analysis using Indian Standard Test Sieves. The size of the VSK separator is established based on the d50 value derived from a graph correlating the average size in microns with the percentage of coarse particles in the feed area. The cut size of the VSK separator was determined by the d50 values obtained from a graph illustrating the average size in microns versus the percentage of coarse particles in the feed.

Table 1. Sink float studies on close size fractions obtained by dry and wet methods.

Size, µm	Dry method		Wet method	
	Wt%	THM%	Wt%	THM%
−1000+600	5.3	0.1	4.3	0.10
−600+420	14.5	0.3	24.0	0.25
−420+300	20.6	0.7	40.3	0.51
−300+210	39.7	2.8	13.6	1.26
−210+150	12.5	3.5	11.4	1.90
−150+100	5.4	3.5	4.8	2.53
−100+75	1.2	1.1	1.3	3.06
−75+45	0.7	0.7	0.2	2.15
−45	0.2	0.2	0.1	1.14
Total	100.0	12.9	100.0	12.90

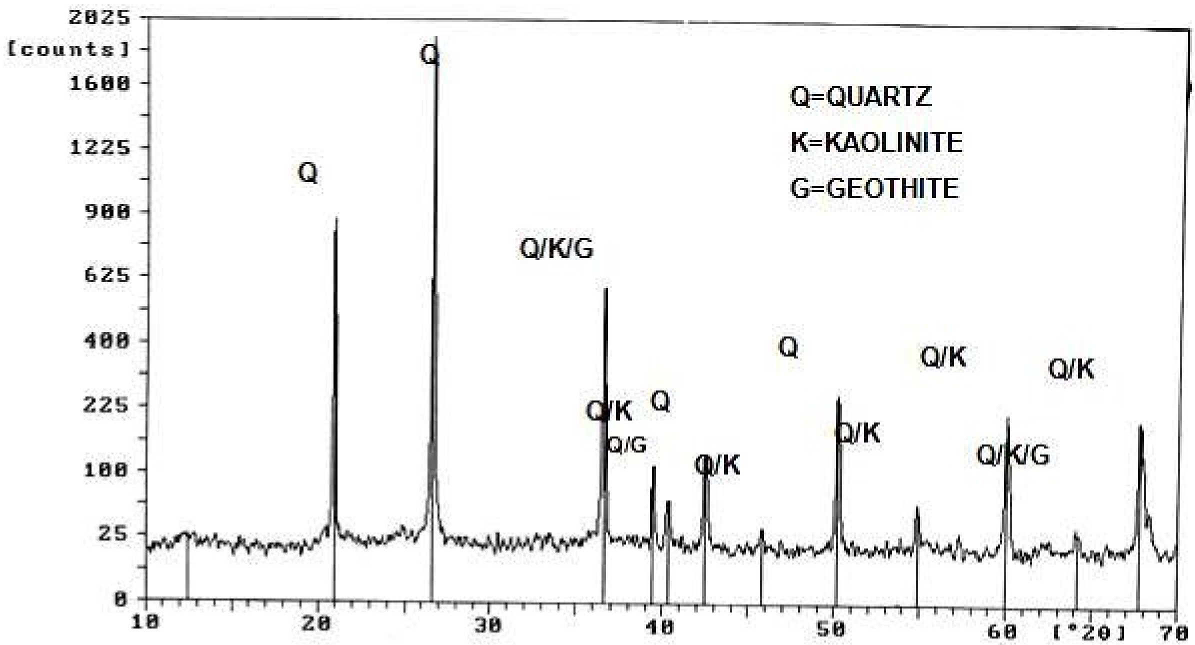

Fig. 4. XRD pattern of the aeolian red sand dune sample.

$$\%\ \text{Coarse particles responded in the feed} = \frac{\text{Weight dist.\% of coarse size fraction in product}}{\text{Weight\% of coarse size fraction in calculated feed}}$$

The separation efficiency of the VSK separator is calculated by dividing the difference between d75 and d25 by 2. Sink and float tests were performed using bromoform (specific gravity 2.89) to determine all heavy minerals present in the product. Diiodomethane, also known as Methylen iodide, was employed to further segregate the components of exceedingly dense minerals [Very Very heavy minerals] within the heavy fraction acquired through the utilization of bromoform.

3. RESULTS AND DISCUSSIONS

3.1. Characterization of feed sample

The sand sample that was obtained contains slight moisture content, exhibits a free-flowing nature, and has a reddish hue. This colouration is attributed to the presence of fine ferruginous materials coating the sand particles. Extensive analysis has been conducted on the physical properties of the sample, including its bulk density of 1.7 g/cc, true density of 2.8, porosity of 41.5%, d80 passing size of 415 microns (dry method) and d80 passing size of 710 microns (wet method), the total heavy mineral content 12.9% (Table 1), total magnetic minerals 9.7%, and total non-magnetic minerals 3.2%. In other way the sample contains very heavy minerals such as ilmenite, zircon, rutile, garnet, monazite, etc. making up 9.6% by weight, and light heavy minerals such as sillimanite and pyrabols accounting for 3.3% by weight. Quartz, a light mineral, makes up 91.2% by weight. The XRD data of −63 micron size fraction of the sample is shown in Fig. 4. The data indicate that quartz is major mineral present in the samples followed by kaolinite and goethite.

Table 2. Design of experiments by using VSK separator.

Expt.No	Cage wheel (rpm)	Screw feeder (rpm)	Air rate (Hz)	Moisture%
1.	400	800	49	0.5
2.	400	1200	49	0.5
3.	1200	800	49	0.5
4.	1200	1200	49	0.5
5.	400	800	49	2.0
6.	400	1200	49	2.0
7.	1200	800	49	2.0
8.	1200	1200	49	2.0
9.	400	800	9	2.0
10.	400	1200	9	2.0
11.	1200	800	9	2.0
12.	1200	1200	9	2.0
13.	400	800	9	0.5
14.	400	1200	9	0.5
15.	1200	800	9	0.5
16.	1200	1200	9	0.5

Table 3. VSK coarse and fine separation test results (Experiment no.1), (Screw feeder: 800; Cage wheel: 400; Air rate: 49; Moisture: 0.5%).

Size in µm	Coarse		Fines	
	Wt%	Cum weight%	Wt%	Cum Weight%
1000	–	100.0	–	–
−1000+600	4.6	95.4	–	100.0
−600+420	17.9	77.5	1.0	99.0
−420+300	26.5	51.0	9.8	89.2
−300+210	31.8	19.2	47.1	42.1
−210+150	12.0	7.2	21.5	20.6
−150+100	3.9	3.3	7.9	12.7
−100+63	2.7	0.6	8.5	4.2
−63	0.6	–	4.2	–
Total	100.0		100.0	

Table 4. Size analysis of VSK products (Experiment no.1) (Screw feeder: 800; Cage wheel: 400; Air rate: 49; Moisture: 0.5%).

Size in µm	Average size in µm	Coarse wt%	Fines wt%	Wt dist% of Coarse	Wt dist% of fines	Feed calculated wt%	% coarse responded from the feed
−1000+600	800	4.6	0	2.2	0	2.2	100
−600+420	510	17.9	1.0	9.0	0.5	9.5	94.7
−420+300	360	26.5	9.8	13.0	4.8	17.8	73.0
−300+210	255	31.8	47.1	15.7	23.8	39.5	39.7
−210+150	180	12.0	21.5	6.0	11.0	17.0	35.3
−150+100	125	3.9	7.9	2.0	4.0	6.0	33.3
−100+63	82	2.7	8.5	1.3	4.2	5.5	23.6
−63	32	0.6	4.2	0.3	2.2	2.5	12.0
Total	–	100.0	100.0	49.5	50.5	100.0	–

3.2. Optimizing the VSK separator to recover fines by using design of experiments

The design of experiments by using VSK separator with different variables as in put to carry out the experimental is given in Table 2. The typical results from out of sixteen experiments carried out by using this unit at minimum and maximum feeder (rpm), cage wheel speed (rpm), air rate (Hz) and moisture content (%) are shown in Tables 3 and 4 and Figs. 5 and 6. The d50 and d80 of the VSK coarse and fines are products determined from the graphs plotted size vs. cumulative weight percent passing. The percentage of coarse size responded from the feed vs. average size in microns plotted to determine the effective size separation of VSK unit. These typical test results obtained from the data Tables 3 and 4 and Figs. 4 and 5 are presented in Tables 5 and 6 and Figs. 7 and 8 to determine the effective size separation of VSK unit.

The summary of sink float data obtained on coarse and fines and effective size separation of VSK separator are shown in Table 7. The data indicate

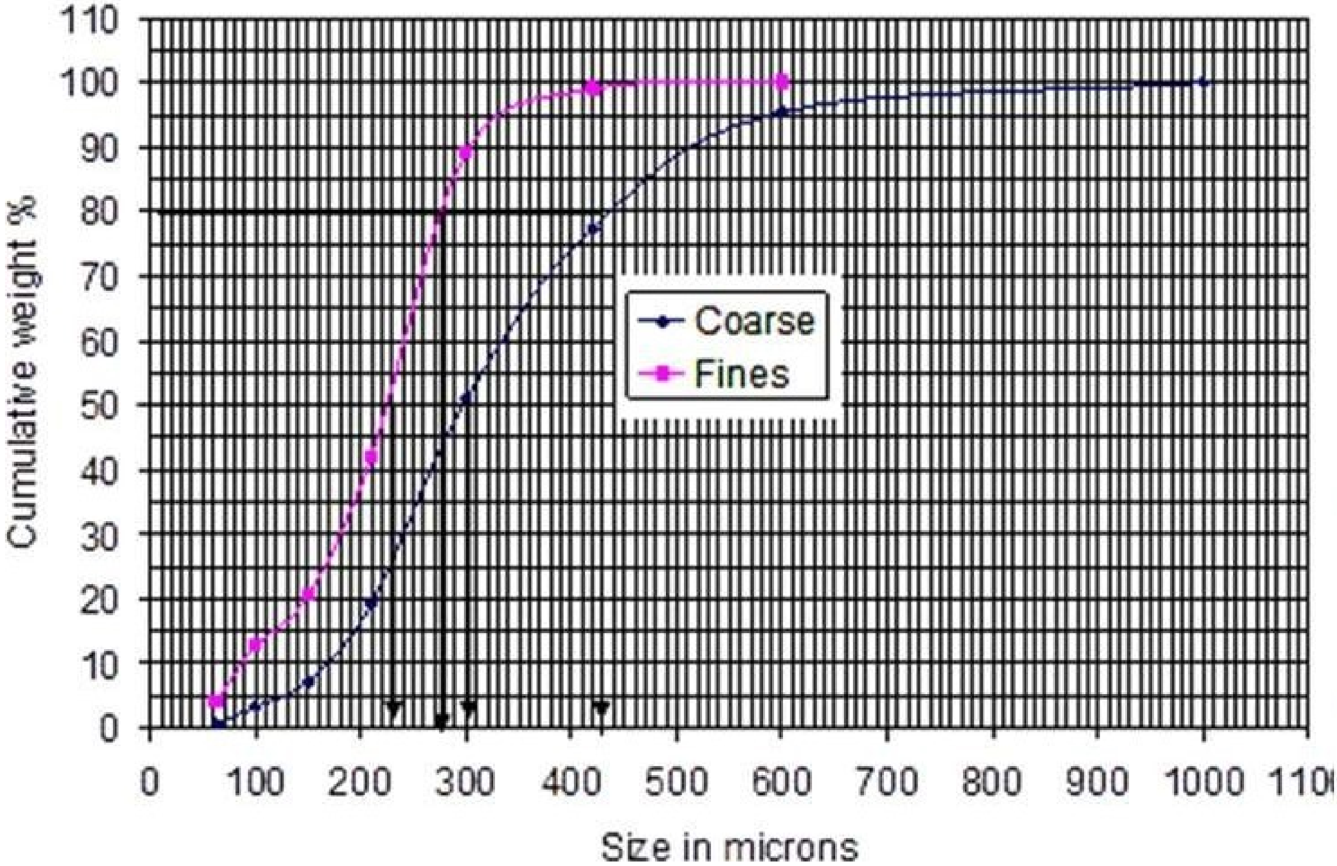

Fig. 5. VSK coarse-fine separation results (Screw feeder: 800; Cage wheel: 400; Air rate: 49; Moisture: 0.5%).

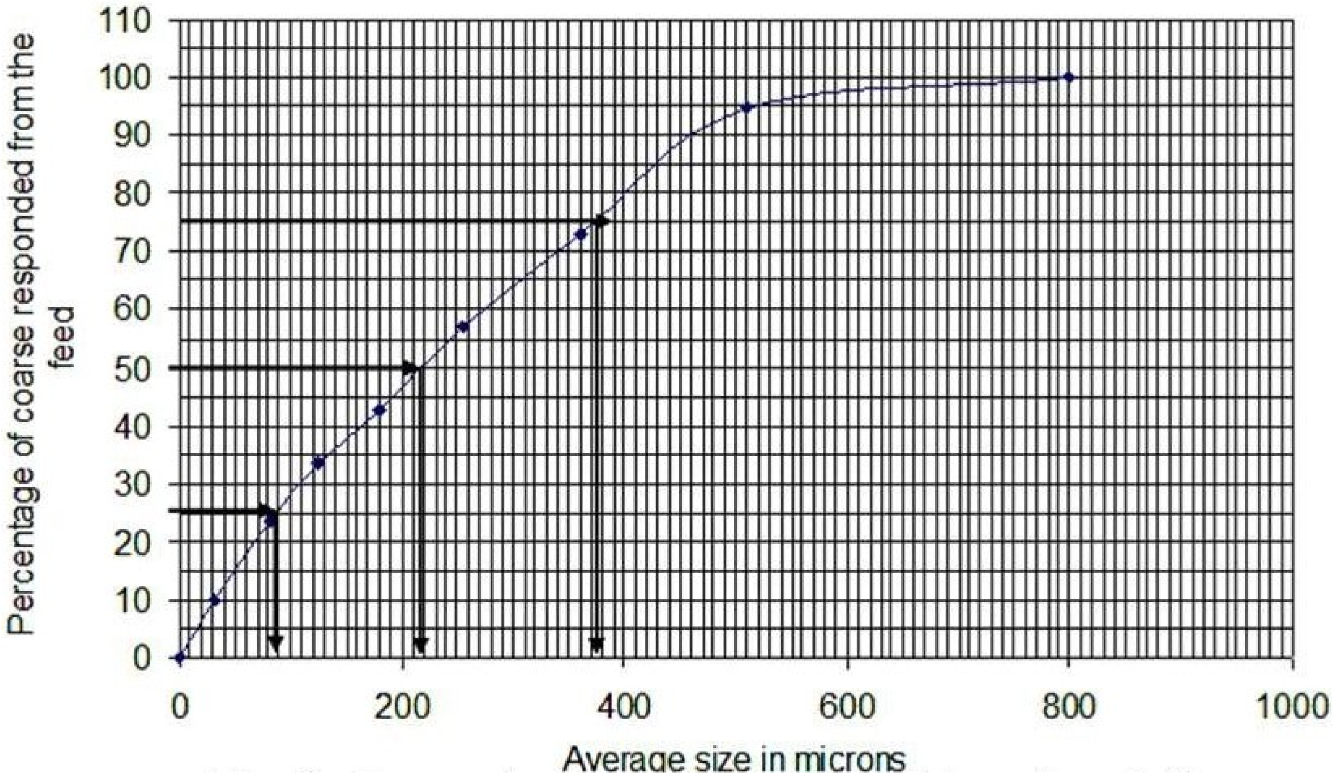

Fig. 6. Size analysis of VSK product (Screw feeder: 800; Cage wheel: 400; Air rate: 49; Moisture: 0.5%).

Table 5. VSK coarse and fine separation test results (Experiment no.16) (Screw feeder: 1200; Cage wheel: 1200; Air rate: 9; Moisture: 0.5 %).

Size in μm	Coarse Wt%	Cum weight%	Fines Wt%	Cumulati ve weight%
1000	–	100.0	–	100.0
−1000+600	10.6	89.4	–	100.0
−600+420	2.6	86.8	–	100.0
−420+300	50.1	36.7	15.9	84.1
−300+210	23.6	13.1	42.5	41.6
−210+150	8.5	4.6	21.1	20.5
−150+100	3.2	1.4	13.1	7.4
−100+63	0.7	0.7	4.0	3.4
−63	0.7		3.4	–
Total	100.0		100.0	

Table 6. Size analysis of VSK products (Experiment no.16) (Screw feeder: 1200; Cage wheel: 1200; Air rate: 9; Moisture: 0.5%).

Size in μm	Average size in μm	Coarse wt%	Fines wt%	Wt dist% of coarse	Wt dist% of fines	Feed calculated wt%	% coarse responded from the feed
−1000+600	800	10.6	0	7.0	0	7.0	100.0
−600+420	510	2.6	0	1.7	0	1.7	100.0
−420+300	360	50.1	15.9	32.9	5.5	38.4	85.7
−300+210	255	23.6	42.5	15.5	14.6	30.1	51.5
−210+150	180	8.5	21.1	5.5	7.2	12.7	43.3
−150+100	125	3.2	13.1	2.1	4.5	6.6	31.8
−100+63	82	0.7	4.0	0.5	1.4	1.9	26.3
−63	32	0.7	3.4	0.5	1.1	1.6	31.2
Total	–	100.0	100.0	65.7	34.3	100.0	

Table 7. Design of experiments and summary of results obtained by using VSK separator.

Input data					Out put performance							
Exp No	Cage wheel (rpm)	Screw feeder (rpm)	Air rate (Hz)	Moisture%	Separation size, μm [d75–d25/2]	Cut size, μm	Coarse Size			Fine Size		
							Average size, d50	THM%	THM Rec., %	Average size, d50	THM%	THM Rec., %
1.	400	800	49	0.5	145	220	300	6.0	70	280	2.8	30
2.	400	1200	49	0.5	115	265	310	5.4	61	220	3.4	39
3.	1200	800	49	0.5	105	130	290	5.7	65	220	3.1	35
4.	1200	1200	49	0.5	105	170	350	6.0	69	215	2.8	31
5.	400	800	49	2.0	145	165	280	5.4	67	225	3.4	33
6.	400	1200	49	2.0	130	140	245	5.7	65	190	3.1	35
7.	1200	800	49	2.0	110	135	250	5.6	62	175	3.2	38
8.	1200	1200	49	2.0	105	130	325	6.5	74	225	2.3	26
9.	400	800	9	2.0	155	210	320	4.7	54	225	4.1	46
10.	400	1200	9	2.0	160	210	335	4.1	46	245	4.7	54
11.	1200	800	9	2.0	95	180	335	5.5	58	200	3.2	42
12.	1200	1200	9	2.0	102	160	315	6.3	71	210	2.5	29
13.	400	800	9	0.5	155	235	290	6.2	69	210	2.6	31
14.	400	1200	9	0.5	140	215	340	5.2	60	235	3.6	40
15.	1200	800	9	0.5	110	187	305	4.1	46	220	4.7	54
16.	1200	1200	9	0.5	105	100	325	6.2	70	230	2.6	30

that at maximum cage wheel speed of 1200 rpm and feeder speed of 1200 rpm the recovery of THM% (6.5%) is found to be maximum. This observation is constant at air rate 49 and 9 Hz and moisture content 2% and 0.5%. Similarly, it is also observed that the effective separation size is 105 microns at above operating conditions.

The conceptual flow sheet with material balance for weight distribution of coarse and fines as well as the THM% and light heavy minerals (LHM%) are

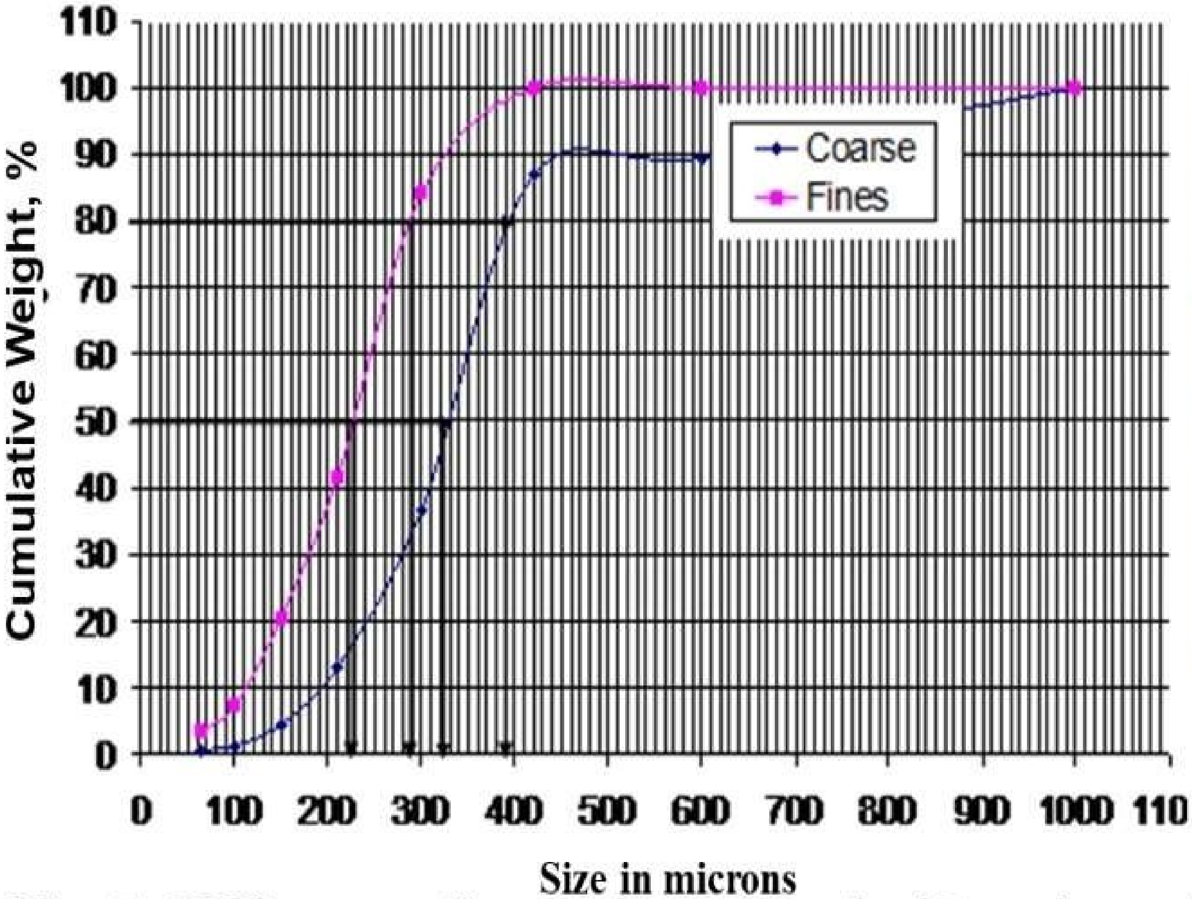

Fig. 7. VSK coarse-fine separation results [Experiment 16] (Screw feeder: 800; Cage wheel: 400; Air rate: 49; Moisture: 0.5%).

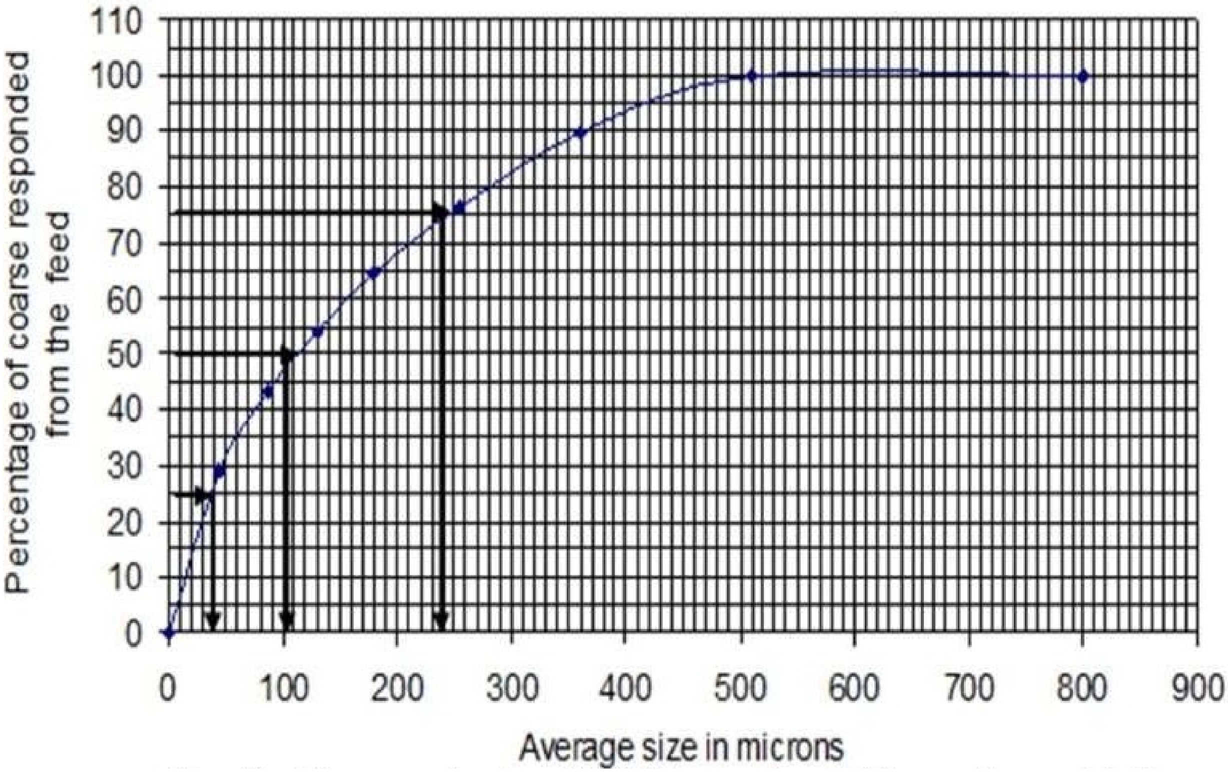

Fig. 8. Size analysis of VSK product [Experiment 16] (Screw feeder: 800; Cage wheel: 400; Air rate: 49; Moisture: 0.5%).

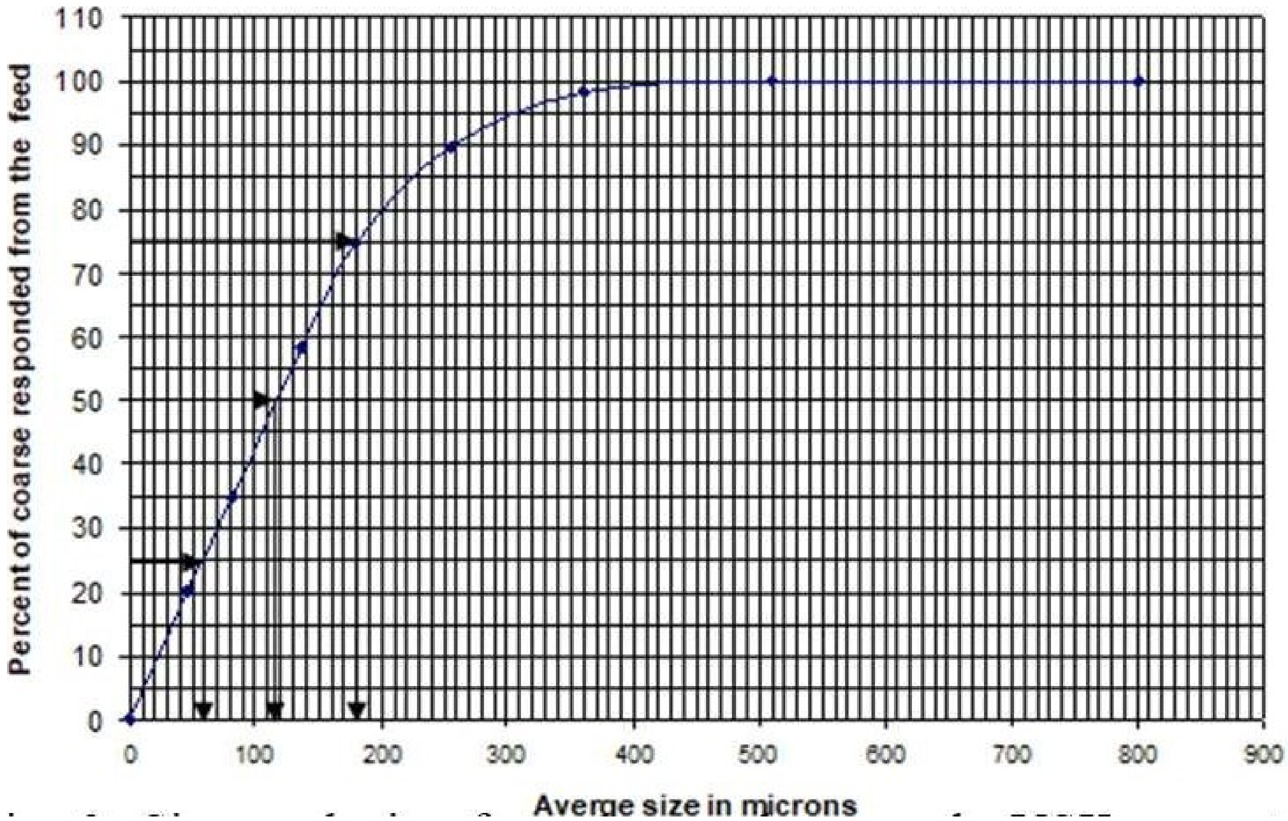

Fig. 9. Size analysis of continuous large scale VSK separator rougher coarse products [Feeder: 1800 rpm, Air Rate, Hz: 49, Cage Wheel: 1800 rpm, Moisture, %: 0.5, Feed Rate, Kg/hr: 210].

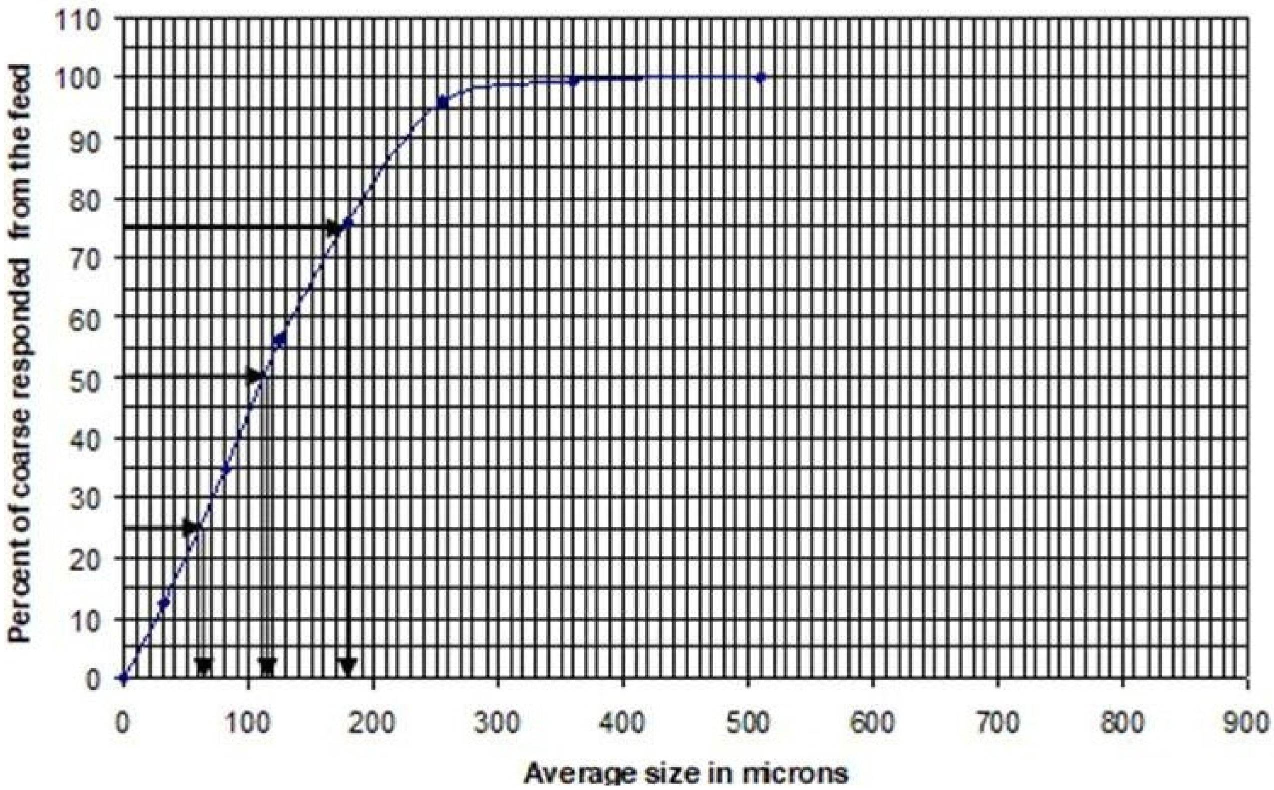

Fig. 10. Size analysis of continuous large scale VSK cleaner products (Rougher coarse/coarse) obtained from rougher coarse (Fig. 9).

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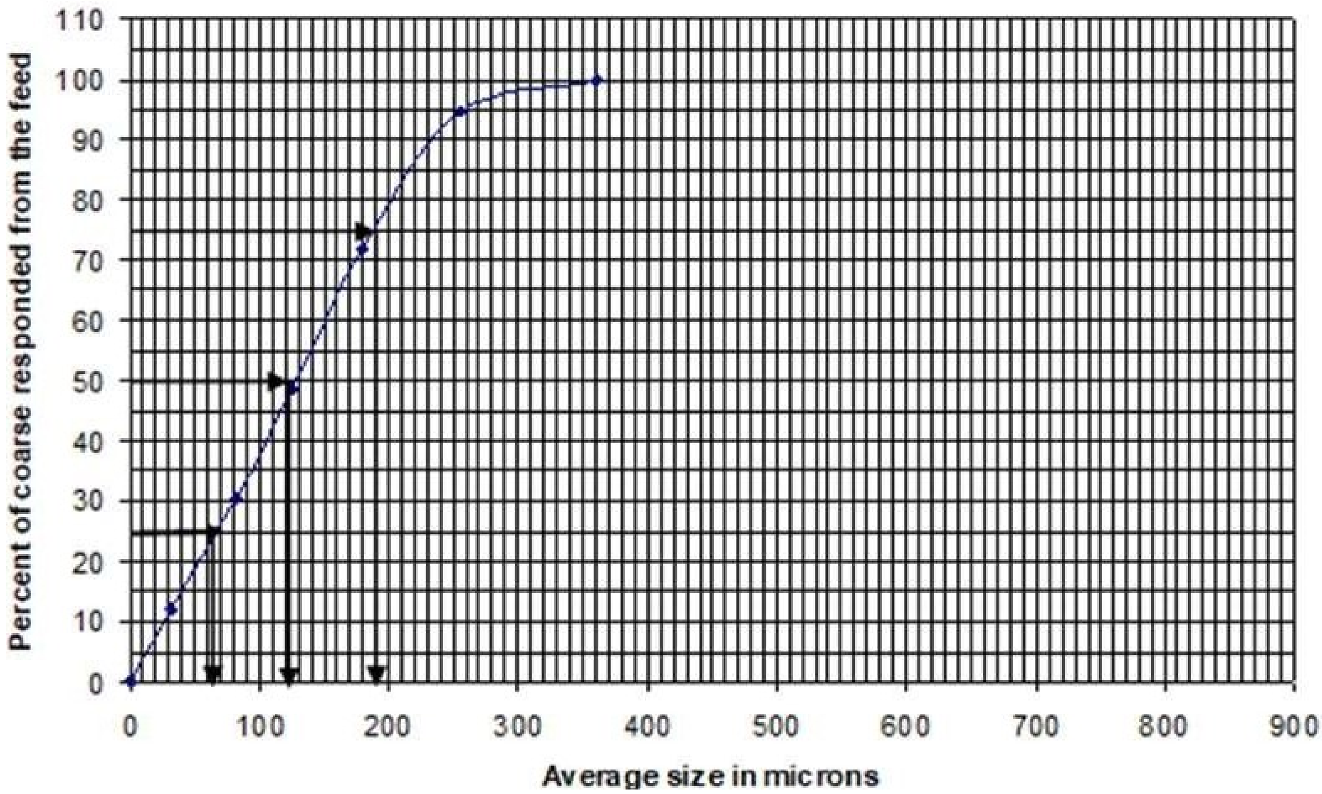

Fig. 11. Size analysis of continuous large scale cleaner -coarse VSK products.

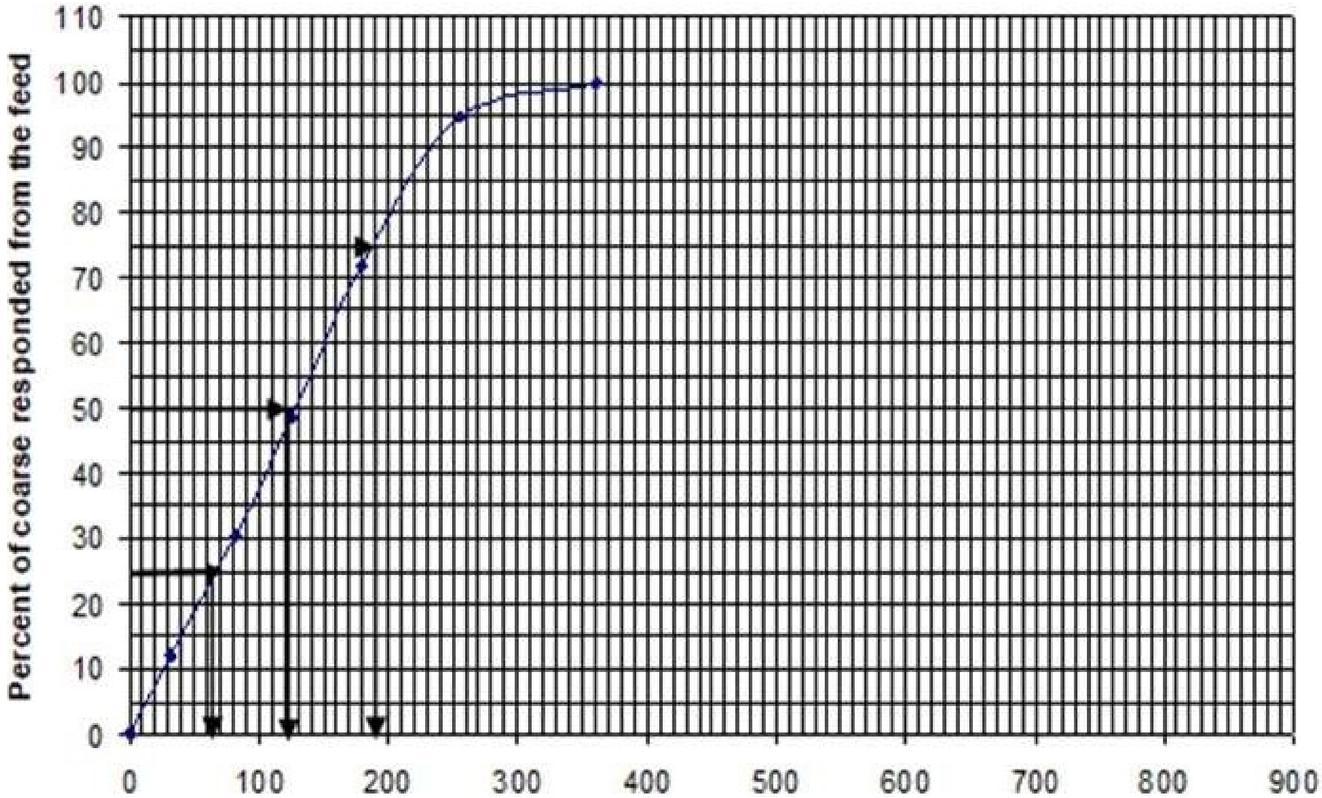

Fig. 12. Size analysis of continuous large scale VSK cleaner fines.

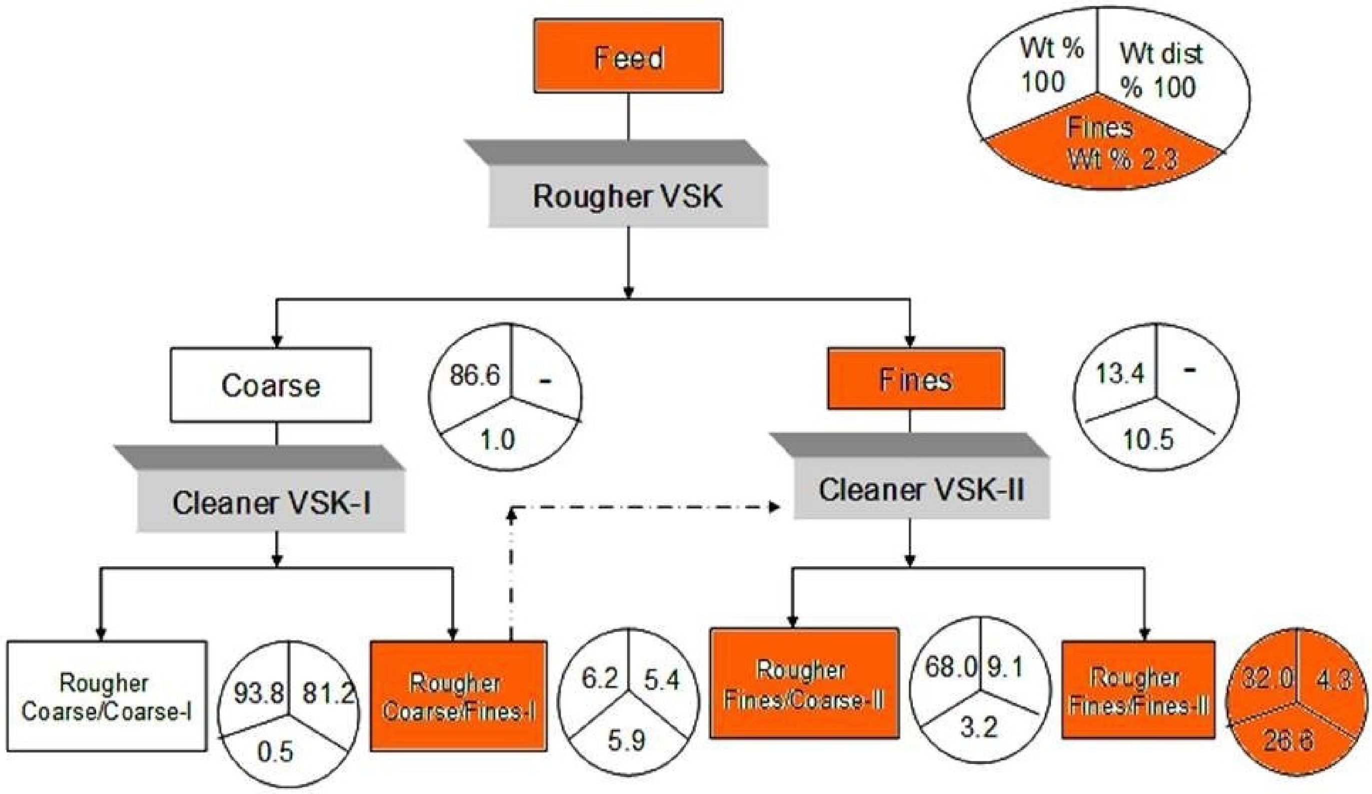

Fig. 13. Flowsheet with mass balance on reduction of slit/slimes from aeolian red sand dune sediment.

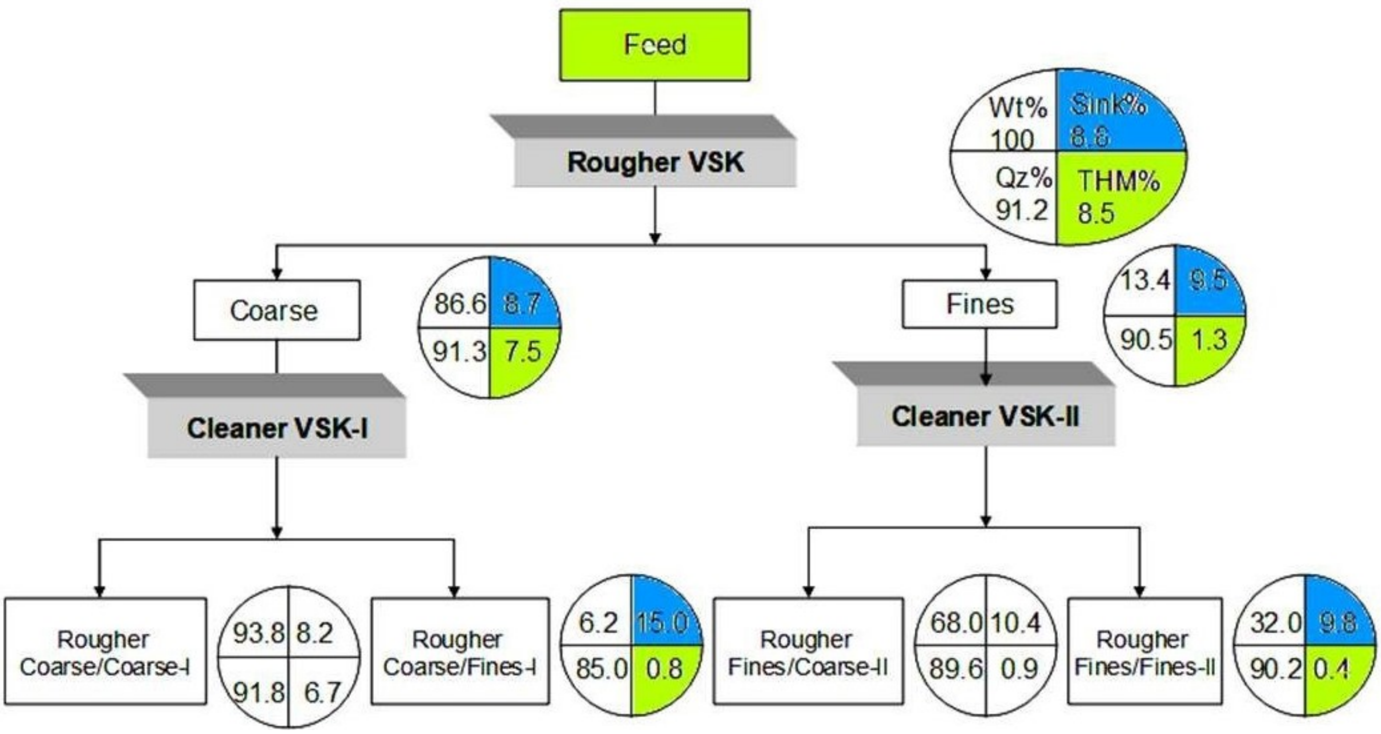

Fig. 14. Flowsheet with mass balance on recovery of THM in corase and fine fractions using VSK separator from aeolian red sand dune sediment.

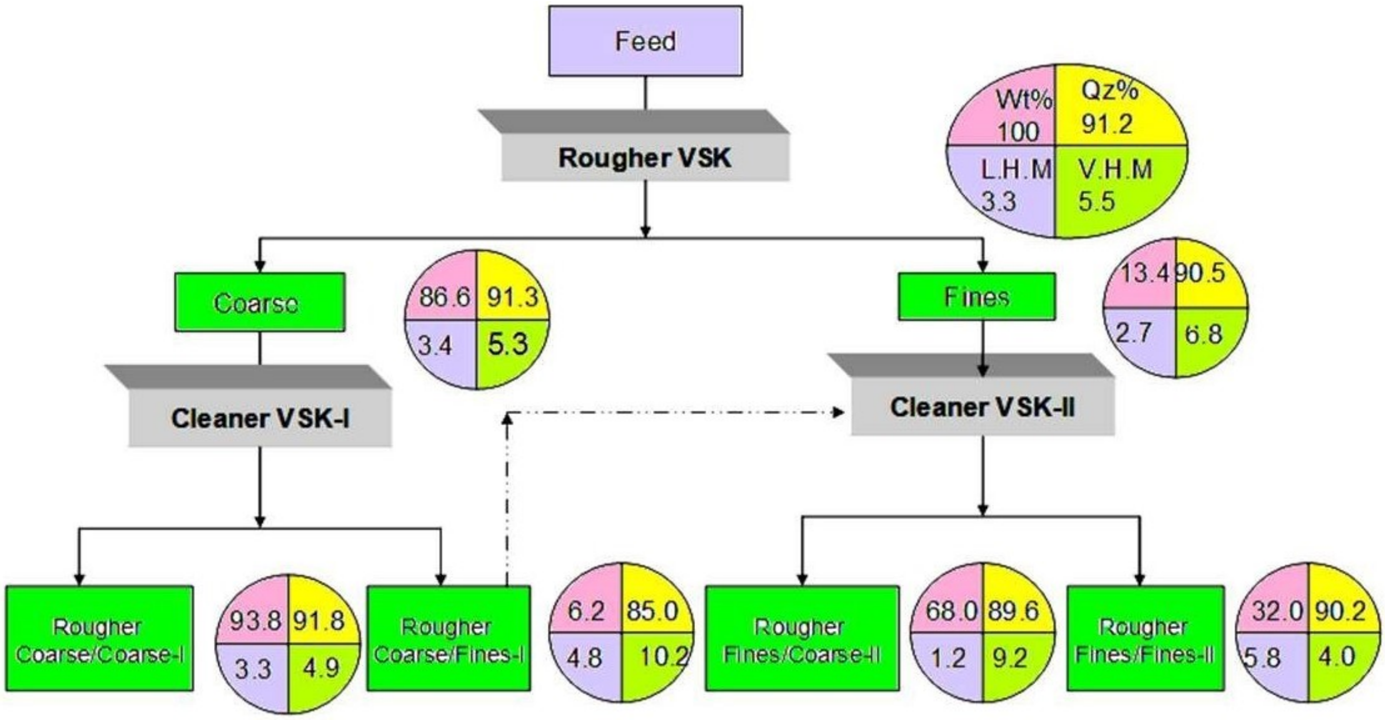

Fig. 15. Flowsheet with mass balance on recovery of VHM & LHM in corase and fine fractions using VSK separator from aeolian red sand dune sediment.

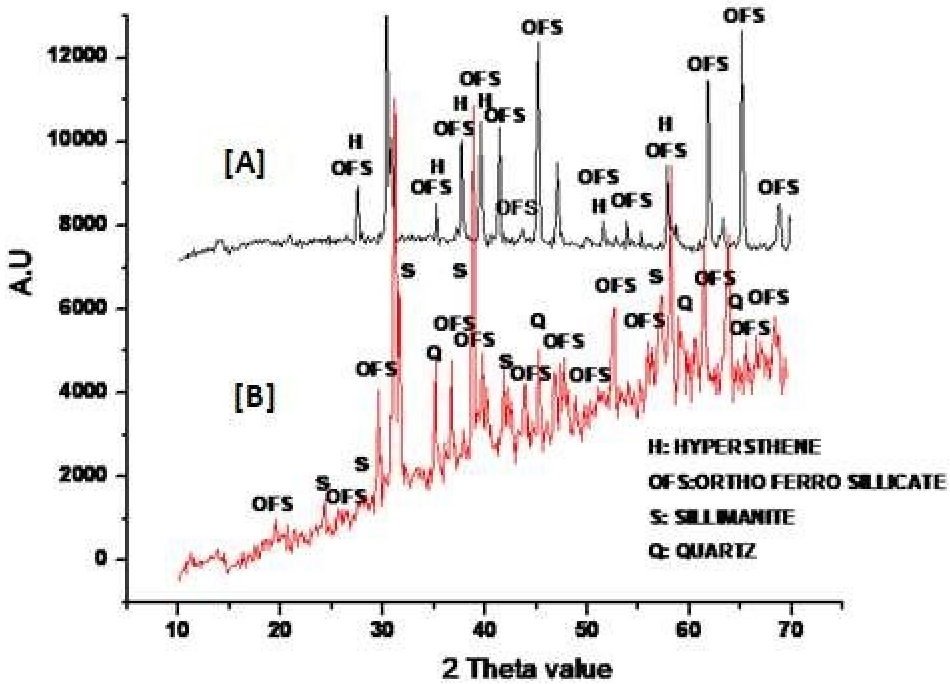

Fig. 16. XRD pattern of rejectable rougher [A]coarse-fine and [B]rougher fine-fine fractions.

given in Figs. 14 to 16. The data indicate that on reprocessing of the rougher fines with 10.7% by weight can produce 26.6% of fines (−63 µm). The sink float data (Fig. 14) indicate that the rougher coarse contains 8.7% sink and rougher fines contain 9.5% sink. The sinks of these fines are further subjected to methylene iodide sink float tests. The data indicate that, the fines contain light heavy minerals (LHM) (Fig. 15).

Typical XRD patterns of VSK products such as rougher coarse, cleaner fines and fines from recirculation of coarse shown in Fig. 16 indicate that rougher coarse light heavy minerals contain mostly sillimanite, whereas the cleaner fines contain mostly pyrobols (>3.2 sp.gr) such as pyroxene and amphibole silicate minerals which has got no commercial value. Hence these fines can be rejected from the circuit. Several researchers (Babu et al., 2009; Laxmi et al., 2011) have studied the detailed characterization of these red sediments and reported apart from heavy minerals, there are other heavy minerals which are not economic values. Only the present investigation could specify the pyribol minerals by studying with VSK separator.

4. CONCLUSIONS

The mineralogical distribution in the ROM estimated based on the sequential sink and float studies at 2.89 and 3.3 liquid media specific gravities reveals that the ROM sample contains 91.2% quartz (bromoform float), 3.3% [(methyl iodide float), light heavy minerals (LHM, such as pyribols)] and 5.5% very heavy minerals (methyl iodide sink). The results of size analysis indicate that the sample contain 2.3% fines. The results of VSK separator indicate that by single stage operation, the fines obtained contain 13.4% by weight. Summary of results obtained from VSK separator reveals that the coarse fraction contains 90.2% by weight with 5.7% VHM and 3.1% LHM, whereas the fines contain 9.8% by weight with 2.8% VHM and 5.3% LHM. Thus, the results confirm that the VSK separator can remove fines and also assisting in removing of some light heavy minerals like pyroxenes and amphiboles, which has no commercial value and poses problems in down-stream mineral processing. Based on the results of VSK separator, it is suggested that an air classifier may be introduced prior to feeding the sample for scrubbing and spirals. By introducing an air classifier, the unwanted slimes and non-commercial minerals such as pyriboles' can be rejected prior to wet circuit. Thus, it minimizes the downstream water pollution and also water consumption as well as improves the economics of the plant.

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References

Babu, N., Vasumathi, N., Bhima Rao, R., 2009. Recovery of Ilmenite and other Heavy Minerals from Teri Sands (Red Sands) of Tamil Nadu, India. *Journal of Minerals and Materials Characterization and Engineering* 08(02), 149–159. https://doi.org/10.4236/jmmce.2009.82013.

Bhima Rao, R., 2007. *Feasibility studies on reduction of slimes from Tamilnadu mineral sand deposit by using VSK separator*. TATA STEEL, Jamshedpur.

Bhima Rao, R., 2012. *Studies on the use of advanced air cyclone for separation of zircon and sillimanite concentrates from non-conducting–non-magnetic fraction of IREL mineral separation plant, Chatrapur, Orissa*. M/s. IREL, Chatrapur.

Bhima Rao, R., Das, B., 2008. *Feasibility studies on reduction of silica content from Sattankulam limestone by using VSK separator*. Madras Cements Limited, Chennai.

Chandrasekharan, S., Murugan, C., 2001. Heavy minerals in the beach and the coastal red sands (TERIS) of Tamil Nadu. *Exploration and Research for Atomic Minerals* 13, 87–109.

Jayangondaperumal, R., 2014. Teri Red Sands, Tamil Nadu, in: Landscapes and Landforms of India, p. 211–216. https://doi.org/10.1007/978-94-017-8029-2_22.

Jayangondaperumal, R., Murari, M.K., Sivasubramanian, P., Chandrasekar, N., Singhvi, A.K., 2012a. Luminescence dating of fluvial and coastal red sediments in the SE coast, India, and implications for paleoenvironmental changes and dune reddening. *Quatern Res* 77, 468–481. https://doi.org/10.1016/j.yqres.2012.01.010.

Jayangondaperumal, R., Murari, M.K., Subramaniam, P., Singhvi, A.K., 2012b. Luminescence dating of Teri Red Sands in the SE coast, India: Implications for Environmental changes and dune reddening. *Quaternary Research* 77, 468–481. https://doi.org/10.1016/j.yqres.2012.01.010.

Laxmi, T., Nishad, P., Jayadevan, K.E., Bhima Rao, R., 2011. Textural and Concentration Pattern of Heavy Minerals in red sediments of Badlands Topography Bhimunipatnam,Visakhapatnam Dist., India. *Journal of Mining and Metallurgy* 47A(1),75-91.

Mir Azam Ali, Krishnan, S., Banerjee, D.C., 2001. Beach and Inland Heavy Mineral Sand Investigations and Deposits In India - An Overview. *EARFAM* 13.

Perumal, V., Udayanapillai, A.V., 2019. Micromorphology and major element geochemistry of calcretes in the Thoppukulam mine section, Sathankulam region, Southern Tamil Nadu, India: implications on depositional environment. *Arab J Geosci* 12(385), 1–12. https://doi.org/10.1007/s12517-019-4544-4.

Perumal, V., Udayanapillai, A.V., 2020. Calcrete profiles in Puthukulam quarry section, Sathankulam region, Southern Tamilnadu, India: implications on palaeoclimate significance. *J Sediment Environ* 5, 493–503. https://doi.org/10.1007/s43217-020-00029-0.

Thrivikramji, K.P., Joseph, S., Anirudhan, S., 2008. Teris of Southern Tamilnadu: a saga of Holocene climate change. *Memoirs of Geol Soc India* 74, 351–359.

Udayanapillai, A.V., Ganesamoorthy, P., 2013. Mineralogical and geochemistry of red and black sediments Thoothukudi District Tamilnadu India. *J Geol Soc of Sri Lanka* 15, 47–

56. URL: https://api.semanticscholar.org/CorpusID:130286283.

Udayanapillai, A.V., Perumal, V., Armstrong-Altrin, J.S., Satyanarayanan, M., 2016. Micromorphology, Geochemistry and Spatial evaluation of Calcrete deposits in and around Sathankulam, Tuticorin District, Tamilnadu, India. *J Geosci Research* 1(2), 111–118.

Venu, U.A., Velmayil, P., 2021. Texture, mineralogy and geochemistry of Teri sediments from the Kuthiraimozhi deposit, Southern Tamilnadu, India: implications on provenance, weathering and palaeoclimate. *Arabian Journal of Geosciences* 14, (5) 364, 1–15. https://doi.org/10.1007/s12517-021-06549-x.