International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

Particle Size Distribution Study of China Clay Deposits of Nagaur Area, Rajasthan, India

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Abstract: ***Two prominent deposits of china clay are occurring in Nagaur area, Rajasthan. These deposits occur as horizontal sub-surface beds of variable thickness. The deposits occur in association with recent to sub-recent sediments of the Marwar Supergroup. The china clay produced from the area is greyish-white to creamish-white in colour and poor in silica. The deposits are being developed and utilized by open-cast, semi-mechanized methods of mining. Nearly 50% china clay produced from the area is found suitable for its use in ceramic industry. This study is focused on particle size distribution analysis of four china clay samples using laser diffraction technique. The analytical data suggest that out of four samples of china clay, two have moderately good plasticity and rest of two shows poor plasticity.***

Keywords: China clay, Particle size distribution, Laser diffraction technique, Nagaur, Rajasthan

1. Introduction

In India, clay deposits occur in several states but, the state of Rajasthan is one of the leading producers of china clay in the country. It accounts for about 16% of the total national production of china clay (IBM, 2017). China clay is generally formed by chemical weathering of alumino-silicate minerals like feldspar, felspathoids etc. (Deer et al., 1971). The china clay also known as kaolin is consists mainly of the mineral kaolinite (Al_2O_3 $2SiO_2$ $2H_2O$). It is a micro-crystalline mineral characterized by its softness, non-swelling nature on addition of water, chemical inertness over wide range of pH (4.5 to 7.0), low conductivity of heat and electricity etc. The china clay produced in India is used in processed and unprocessed forms. The processed china clay finds its use in several industries such as ceramic, textile, paper, rubber, cosmetic, pharmaceutical etc. Whereas, the unprocessed china clay is used in cement, refractory and insecticide industries. The cement industry utilizes a large quantity of unprocessed china clay for production of Portland cement (Shekhawat and Sharma, 2009). Similarly, ceramic industry also consumes a large quantity of china clay for manufacturing a number of products.

The particles of china clay are mostly hexagonal in outline and vary in size from 0.05 to 10 µm. The particle size distribution is an important physical property of china clay which determines its use in ceramic industry. Thus, in present study, four representative china clay samples of the study area have been analyzed to understand its suitability in ceramic industry. The analysis was carried out by using Laser diffraction technique at Sophisticated Instrumentation Centre for Applied Research and Testing (SICART) Laboratory, Vallabh Vidyanagar, Anand, Gujarat.

2. Material and Methods

2.1 Field Study

Two prominent deposits of china clay are occurring near the village Junjhala (27°01'45"N: 73°56'14"E) and Indawar (26°32'25"N: 73°54'06"E) in Nagaur district, Rajasthan (**Figure 1**). Junjhala is located about 41 km south of the town Nagaur (27°12'25"N: 73°44'32"E) on NH-58, while, Indawar is located about 15 km south-west of Merta city (26°39'3.6"N: 74°1'34"E).

In the study area, china clay deposits occur as nearly horizontal beds of variable thickness (5 to 10 m). These sub-surface deposits of china clay are covered by a thin layer of fertile soil (1.0 to 3.0 m) followed by poorly compacted layers of kankar, yellowish silica sand, reddish silica sand and white to off-white silica sand. The total thickness of soil cover and these layers of silica sands vary from 10 to 20 m.

In the study area, the State Government has granted about 150 mining leases for the production of china clay. The deposits are being developed and utilized by open-cast, semi-mechanized methods of mining (**Figure 2**). China clay produced from the area is brought to the ground surface and sorted under different grades by skilled workers on the basis of colour and its composition. The china clay of Junjhala area is white to creamish-white in colour (**Figure 3**) and siliceous in composition while, in Indawar area, it is white to greyish-white in colour and poorly siliceous in nature. For the present study, four fresh and representative samples of china clay were collected from working faces of four different quarries located in the area. The details of these samples are given in **Table 1.**

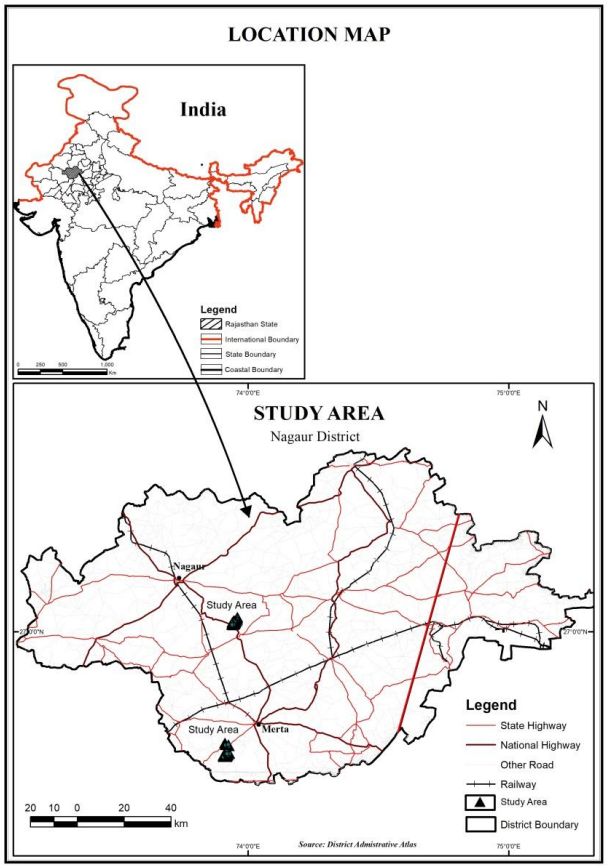

Figure 1: Location map of the study area

Figure 2: Field photograph showing creamish-white china clay produced from Junjhala area

Figure 3: Field photograph showing development of a quarry in Indawar area

Table 1: Details of the china clay samples selected for particle size analysis

Sample No.	Types of china clay	Name of deposits	GPS coordinates of the sample location
A-1	White china clay	Parvati mines, Indawar deposit	N 26º 32' 24.8": E 73º 54' 05.8"
A-3	Creamish-white china clay	Kamla mines, Indawar deposit	N 26º 31' 34.6": E 73º 54' 49.6"
A-4	White china clay	Balaji mines, Junjhala deposit	N 27º 02' 02.5": E 73º 56' 58.4"
A-6	White china clay	Sukhsagar mines, Junjhala deposit	N 27º 02' 50.8": E 73º 57' 09.1"

3. Experimental Work

3.1 Particle Size Analysis:

Traditionally, particle size distribution is determined by mechanical sieving and sedimentation methods for coarse and fine grained materials respectively. These methods are slow and time consuming hence, found unfavorable for particle size determination. Now a days, the laser diffraction technique (LD) is become a primary method for determination of particle size distribution due to its simplicity and accuracy. It is widely used in powder industries because of its high repeatability, rapid results and detection of wide particle size range (Ozer et al., 2010; Felix et al., 2011). The laser diffraction technique is based on the principle that particles passing through a laser beam will scatter light at an angle that is directly related to their size. Small size particles scatter at high angles whereas; large size particles scatter light at low angle. The LD technique is based mainly on Fraunhofer diffraction and Mie theories. The Fraunhofer diffraction theory is not suitable for particles less than 2 µm size whereas, Mie theory correctly explain scattering diffraction and it is a better choice when the particle size is smaller than the wavelength of laser light. In the present study, the particle sizes of china clay samples were determined by using laser particle size analyzer (Sympatec HELOS-BF) at the detection range of 0.1-875 µm. The system can analyze dry powders and wet emulsions. Wet mode of the measurement was used in the present case due to good solubility of china clay in water. Four fresh and representative samples of raw china clay (**Table 1)** were selected for particle size analysis. These samples were dried at 105°C in drying oven for eight hours then grinded manually by using agate mortar and pestle before sieving. The filtered samples were collected for particle size analysis. Distilled water was used as dispersant. The analysis was carried out at the Sophisticated Instrumentation Centre for Applied Research and Testing (SICART) Laboratory, Vallabh Vidyanagar, Anand, Gujarat.

4. Results and Discussion

The results of particle size analysis of china clay samples of the area are shown graphically by **Figure 4 & 5** and also presented in **Table 2.** For systematic study, the particle size data are also categorized in four particle size ranges with their fractions (**Table 3).** The particle size distribution data of clay sample of Indawar area (A-1) shows that the fraction of finer particles (0-10.5 µm**)** is 47.8% and the concentration of coarser particles (61-175 µm) is 1.45%. The average particle size (X50) is 11.56 µm. Similarly, in another sample of Indawar area (A-3), the fraction of finer particles (0-10.5 µm**)** is 63.18% and amount of coarser particles (61-175 µm) is 2.58% with an average particle size (X50) of 7.02 µm. It suggests that 50% particles are smaller than 7.02 µm. The particle size distribution data of clay sample collected from Junjhala area (A-4) shows that concentration of finer particles (0-10.5 µm) is 64.67% and amount of coarser particles is only 0.50%. The average particle size of the sample is 6.33 µm. Similarly, in another sample of Junjhala area (A-6), the concentration of finer particles (0-10.5 µm) is 53.20% and fraction of coarser particles (61-175 µm) is 1.29%. The average particle size of the sample is 9.36 µm.

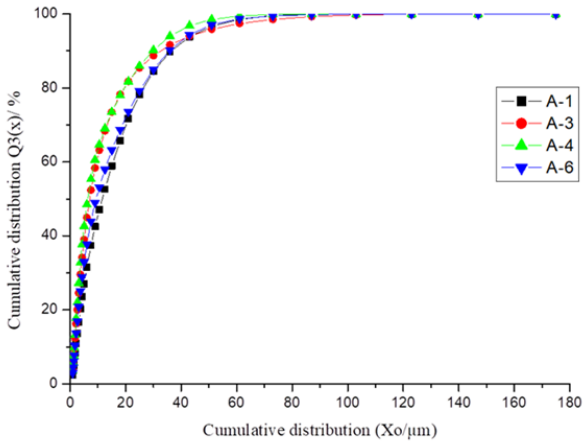

Figure 4: Particle size cumulative distribution curve of china clay samples of Nagaur area, Rajasthan

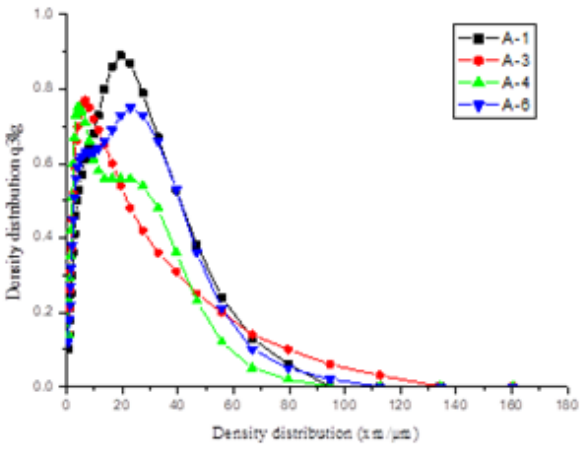

Figure 5: Particle size density distribution curve of china clay samples of Nagaur area, Rajasthan

The particle size distribution of clay materials influences their behaviour during different technological processes and also affects many physico-chimical properties of the clay ceramic products. The mechanical resistance of semi-finished ceramic products is strongly depends on particle size of the clay. It is stated that either higher content of kaolinite or

lower fraction of silica grains results in higher bending strength of the ceramic product (Dondi et al.2003). Plasticity of the clay is also strongly depends on its particle size. Higher percentage of finer particles increases the plasticity of clay (Singer and Singer, 1960; Grimshaw, 1971).

The clay of Parvati mines of Indawar area and Sukhsagar mines of Junjhala area have smaller content of finer particles (0-10.5 μm) which indicates its poor plasticity. The clay sample of Kamla mines of Indawar area and Balaji mines of Junjhala area shows higher amount of finer particles which indicates moderately good plasticity of the clay. The particle size distribution data presented in **Table 3** suggest that clay of Kamla mines of Indawar area and Balaji mines of Junjhala area may find use in ceramic industry after blending with processed and higher grade of clay. The clay of Parvati mines of Indawar area and Sukhsagar mines of Junjhala area is not suitable for its use in ceramic industry because clay should contain 75 to 85% finer particles (< 10 μm) and 5 to 10% coarser particles (< 25 μm) (IS: 2840, 2002). However, it can be suitably used in cement industry for manufacturing Portland cement (Shekhawat and Sharma, 2009; Dashora and Shekhawat, 2020). In addition to particle size, presence of higher amount of ferruginous material as observed in Indawar area also reduces grade of the china clay. White silica sand occurring in association with china clay in both the areas is used in glass and refractory industry after sieving and proper processing.

Table 2: Particle size distribution data of china clay samples of Nagaur area, Rajasthan

Sample →	A-1	A-3	A-4	A-6	Sample →	A-1	A-3	A-4	A-6
X_0/μm ↓	Q3%	Q3%	Q3%	Q3%	xm/μm ↓	q3lg	q3lg	q3lg	q3lg
0.9	2.46	3.7	3.59	2.97	0.67	0.1	0.14	0.14	0.12
1.1	3.72	5.56	5.55	4.52	0.99	0.14	0.21	0.23	0.18
1.3	5.01	7.48	7.65	6.14	1.2	0.18	0.26	0.29	0.22
1.5	6.33	9.43	9.83	7.8	1.4	0.21	0.31	0.35	0.27
1.8	8.33	12.36	13.19	10.32	1.64	0.25	0.37	0.42	0.32
2.2	10.98	16.24	17.67	13.67	1.99	0.3	0.45	0.51	0.38
2.6	13.58	20.02	22.03	16.93	2.39	0.36	0.52	0.6	0.45
3.1	16.72	24.53	27.28	20.8	2.84	0.41	0.59	0.67	0.51
3.7	20.27	29.57	32.79	25.09	3.39	0.46	0.66	0.73	0.56
4.3	23.55	34.16	37.72	28.94	3.99	0.5	0.7	0.75	0.59
5	27.05	38.97	42.65	32.92	4.64	0.53	0.73	0.75	0.61
6	31.53	44.95	48.49	37.84	5.48	0.57	0.76	0.74	0.62
7.5	37.41	52.4	55.35	43.97	6.71	0.61	0.77	0.71	0.63
9	42.52	58.36	60.57	48.99	8.22	0.65	0.75	0.66	0.63
10.5	47.08	63.18	64.67	53.2	9.72	0.68	0.72	0.61	0.63
12.5	52.61	68.37	69.06	58.02	11.46	0.73	0.69	0.58	0.64
15	58.93	73.48	73.5	63.23	13.69	0.8	0.65	0.56	0.66
18	65.75	78.22	77.94	68.72	16.43	0.86	0.6	0.56	0.69
21	71.68	81.81	81.7	73.58	19.44	0.89	0.54	0.56	0.73
25	78.25	85.43	85.97	79.23	22.91	0.87	0.48	0.56	0.75
30	84.52	88.74	90.27	85.05	27.39	0.79	0.42	0.54	0.73
36	89.82	91.62	94.04	90.3	32.86	0.67	0.36	0.48	0.66
43	93.87	94.01	96.85	94.4	39.34	0.53	0.31	0.36	0.53
51	96.67	95.9	98.57	97.1	46.83	0.38	0.25	0.23	0.36
61	98.55	97.42	99.5	98.71	55.78	0.24	0.2	0.12	0.21
73	99.57	98.53	99.87	99.48	66.73	0.13	0.14	0.05	0.1
87	100	99.3	100	99.84	79.69	0.06	0.1	0.02	0.05
103	100	99.77	100	100	94.66	0	0.06	0	0.02
123	100	100	100	100	112.56	0	0.03	0	0
147	100	100	100	100	134.47	0	0	0	0
175	100	100	100	100	160.39	0	0	0	0

Table 3: Particle size distribution data arranged in four categories of china clay samples from Nagaur area, Rajasthan

Particle Size (μm)	A-1	A-3	A-4	A-6
0-10.5	47.8 %	63.18 %	64.67 %	53.20 %
10.5-30	37 %	25.56 %	25.6 %	31.85 %
30-61	14.03 %	8.68 %	9.23 %	13.66 %
61-175	1.45 %	2.58 %	0.50 %	1.29 %

5. Conclusions

On the basis of results of the particle size distribution analysis, it can be concluded that nearly 50% of the china clay produced from the area may be used in ceramic industry after suitable processing and blending with high grade clay. While, rest of the 50% clay is not found suitable for ceramic industry due to high content of coarser particles. However, it can be suitably used in cement industry for making Portland cement and also in abrasive, refractory and insecticide industries where specifications of particle size distribution are not required.

Acknowledgments

The authors are grateful to the Head and Coordinator SAP, Department of Geology, Mohanlal Sukhadia University, Udaipur, Rajasthan for providing required facilities and financial support for completing this work respectively. The Director SICART, Vallabh Vidyanagar, Anand, Gujarat is gratefully acknowledged for providing particle size analysis facilities.

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