Textural characteristics of the lignites from the South-eastern part of Tamil Nadu, India

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Abstract

The current study aims to characterize the lignite samples from the Neyveli block, Veeranam block, and Sikkal block in the southern part of Tamil Nadu, India, within the Tertiary lignite deposits using textural characteristic techniques. The data collected have been analyzed to better understand the dynamic depositional environment of the lignites. A total of 25 lignite samples were collected from different zones and analyzed with a particle size analyzer. The textural characteristics, such as geometric mean, indicate fine to very fine particles; graphic sorting suggests well-sorted to very poorly sorted material; graphic skewness ranges from very coarse skewed to very fine skewed; and graphic kurtosis varies from very leptokurtic to extremely platykurtic. The analysis of results from Mine I and Mine II in the Veeranam block predominantly indicates moderate to high-energy depositional environments, whereas Mine I A and the Sikkal block mainly reflect low-energy depositional settings. These findings help in understanding the depositional dynamics of lignite samples from various southern regions of Tamil Nadu.

Keywords: *Lignite, Neyveli block, Veeranam Block, Sikkal Block, Tamil Nadu, India*

1. Introduction

The Tertiary lignites from the Neyveli, Sikkal, and Veeranam blocks hold significant economic value, mainly serving as a key raw material for power generation in the region. Lignite, a low-rank form of coal, is characterized by its relatively low calorific value, dark brown to black color, and high moisture content. It is a heterogeneous mixture composed of organic materials (macerals) combined with inorganic phases (mineral matter) (Rajak et al. 2018). Coal has unique features that make it suitable for various uses, including electricity production, steel manufacturing, and conversion into liquid and gaseous fuels. Its abundant presence, broad geographic distribution, and lower cost increase its appeal as a fuel for power generation (https://www.iea.org/publications/insights/insightpublications/21stCenturyCoal_FINAL_WEB.pdf). According to the IEA, coal consumption is expected to rise 24% by 2035 compared to 2009 (https://www.iea.org/publications/insights/insightpublications/global_value_of_coal.pdf).

Nearly 99% of the coal reserves are of Gondwana origin, while only about 1% are from the Cenozoic (Paleogene–Neogene) period. Despite their small share, the latter has contributed nearly 75% of the total electrical energy generated (Ministry of Coal, 2024). The exploitation of lignites from the Cuddalore Formation in the Cauvery basin, Tamil Nadu, is known as the largest lignite field in India. According to Neyveli Lignite Corporation India Limited (NLCIL, 2018), the total lignite reserves are estimated at around 34,763 million tonnes, spread across approximately 480 km² in the Neyveli Lignite Fields. Of this, the Neyveli lignite deposits cover about 270 km², with lignite seams found at depths ranging from 45 to 150 meters below the surface. The seams have a combined thickness of less than 25 meters, with total reserves close to 3,300 million tonnes (Balasunder, 1968; Gowrisankaran et al., 1987; NLCIL, 2018). The lignite reserves in Neyveli make up nearly 80% of India's total lignite resources, estimated at around 15,835 million tonnes. Due to this significant endowment, Neyveli Lignite Corporation India Limited (NLCIL) has launched large-scale mining and integrated power generation projects in the region. As a result of these efforts, lignite production reached about 41 million tonnes annually, supporting an installed power capacity of roughly 6,140 MW by 2020.

Particle size and particle size distribution (PSD) are critical physical properties that influence various processes involving ground coal and its derivatives. A review of the literature highlights extensive research on the sizing of different materials, with reported particle sizes typically ranging from 20 to 200 mm, often measured through image analysis techniques. These primarily include coarse particles, which have been well studied, such as aggregates (Tafesse et al. 2012; Fernlund, 1998), fine aggregates (Persson, 1998), crushed limestone (Andersson et al. 2012; Felekoglu, 2009), and coarse coal particles (Zhang et al. 2012). However, there are only a few publications focusing on determining the textural characteristics of fine ground particles. Therefore, this study aims to analyze and provide the textural features of lignite using a particle size analyzer from the Neyveli open cast mining, Veeranam, and Sikkal blocks in the southern part of Tamil Nadu, India. Additionally, the results of this study may help inform the physiochemical characteristics of different lignite blocks from Tamil Nadu.

2. Study area

The Cauvery Basin is an extensive sedimentary basin covering about 81,000 km^2, spanning parts of Tamil Nadu, Karnataka, and Kerala (Nagendra & Nallapa Reddy, 2017). It has a complex evolutionary history shaped by sedimentation, tectonism, and volcanic activity over geological time (Ramkumar et al., 2011). Its development includes successive marine transgressions and regressions, resulting in the buildup of various sedimentary formations. The Neyveli lignite deposits are mainly found in the southeastern part of the basin, within Tamil Nadu. In this area, lignite deposits are primarily linked to the Neyveli Formation, which lies beneath the Cuddalore Formation and overlies the Niniyur Formation.

3. Materials and Methods

In the Cauvery Basin, three lignite mines are currently operational, and a total of eighteen lignite samples have been collected from Mine I, IA, and II in Neyveli, Tamil Nadu, India. Additionally, two temporary lignite samples were taken from the Veeranam block, along with seven lignite samples from the Sikkal blocks of Ramanad, Tamil Nadu, India. The lignite samples were sieved using ASTM sieves ranging from 2 to 0.063 mm (Instrument: Sieve shaker) to classify the different sample sizes, followed by quantifying the size of the lignite particles using the LA-300 Horiba Particle Size Analyzer. The size classification adhered to grain size scales, with categories including 2000 µm (−1 Φ) to 62.5 µm (4 Φ), 62.5 µm (4 Φ) to 3.91 µm (8 Φ), and 8Φ. Grain size parameters such as mean size (Mz), standard deviation (SD), skewness (Sk), and kurtosis (KG) were determined following Folk and Ward (1957) and Blott and Pye (2001).

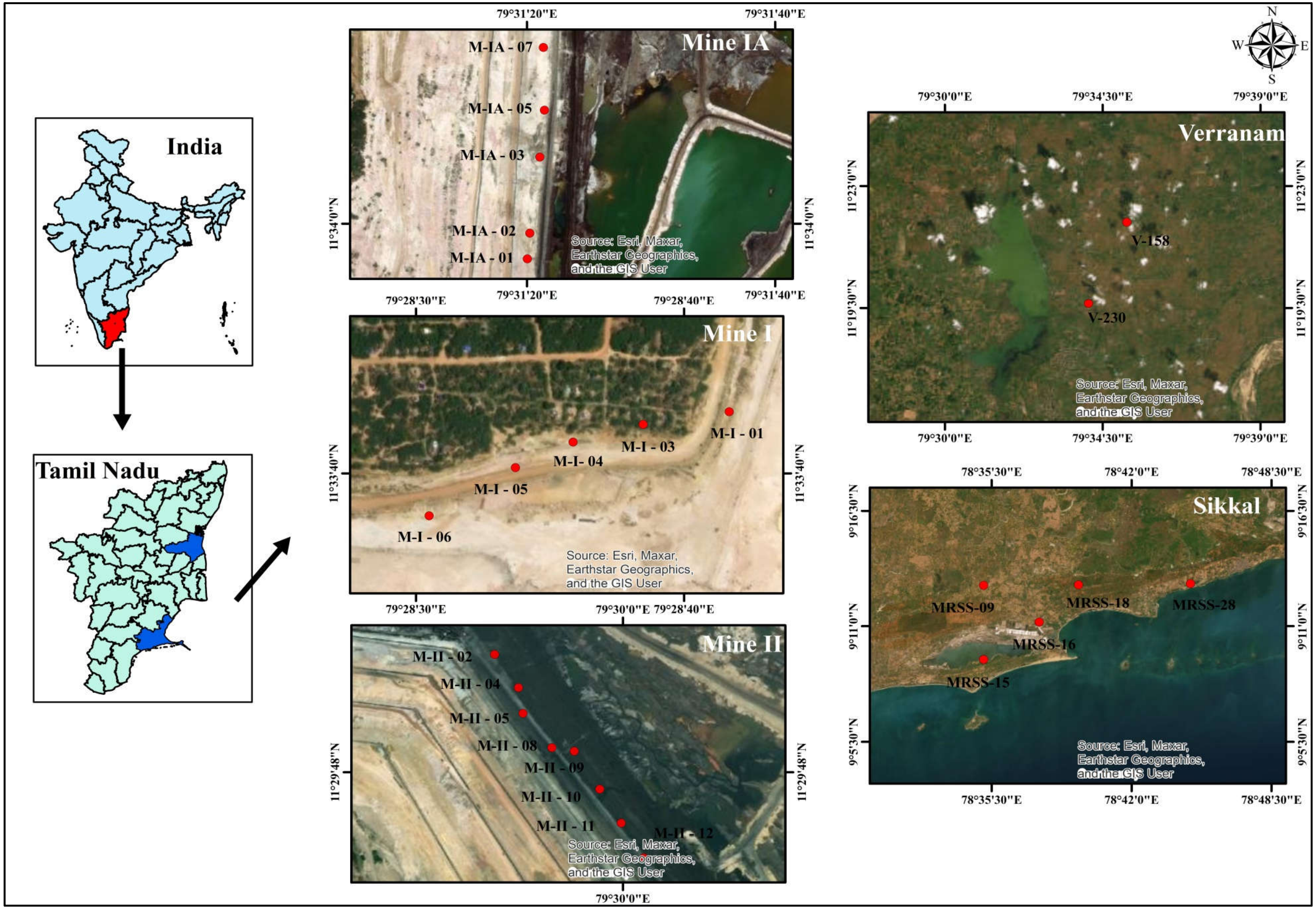

Fig 1 Study area and sample location of the present study

4. Result and Discussion

The primary goal of textural investigations is to identify the grain sizes of sediment deposited in environments. In the study area, the lignite samples in the southern part of Tamil Nadu were texturally classified into Graphic Mean, Graphic Sorting, Graphic Skewness, and Graphic Kurtosis.

4.1 Graphic Mean

The graphic mean is a statistical parameter that quantifies the average grain size of lignite, derived from cumulative particle-size distribution curves. It is calculated using the 16th, 50th, and 84th percentiles of grain-size data, following the method proposed by Folk and Ward (1957). This measure serves as an important indicator of lignite texture and is widely used in reconstructing depositional environments.

$$M_z = \frac{\varphi_{16}+\varphi_{50}+\varphi_{84}}{3} \qquad \text{Eqn. 01}$$

In this study, the Mine I lignite samples range from 7.78 Φ to 9.42 Φ, Mine IA samples range from 6.26 Φ to 9.62 Φ, Mine II shows 4.73 Φ to 9.61 Φ, the Veeranam block indicates 6.39 Φ to 8.04 Φ, and the Sikkal block varies from 4.23 Φ to 9.48 Φ. From these inferences, the lignite samples from all the blocks contain fine to very fine particles, which suggests a low energy environment (Fig 2).

4.2 Graphic Sorting

Graphic sorting is a statistical measure that indicates the degree of grain-size uniformity in particles, thereby reflecting the level of sorting within a sample. It is calculated from the 16th, 84th, 5th, and 95th percentiles of the cumulative grain-size distribution curve, following the method of Folk and Ward (1957). This measure is commonly used in sedimentological studies to deduce depositional processes and the dominant energy conditions of environments.

$$\sigma_I = \frac{(\varphi_{84}-\varphi_{16})}{4} + \frac{(\varphi_{95}-\varphi_{5})}{6.6} \qquad \text{Eqn. 02}$$

In the current study, the lignite samples from Mine I range from 0.43 Φ to 1.25 Φ, Mine IA shows 0.08 Φ to 1.35 Φ, Mine II varies from 0.13 Φ to 2.42 Φ, Veeranam block ranges from 1.42 Φ to 1.68 Φ, and Sikkal block ranges from 0.24 Φ to 2.89 Φ. Based on these observations, the Neyveli mines are classified as well sorted to poorly sorted, Veeranam block as only poorly sorted, and Sikkal block as well sorted to very poorly sorted. These results suggest that the Neyveli mines and Sikkal block predominantly occur in both low and high energy environments, while the Veeranam block indicates a high energy environment (Fig 3).

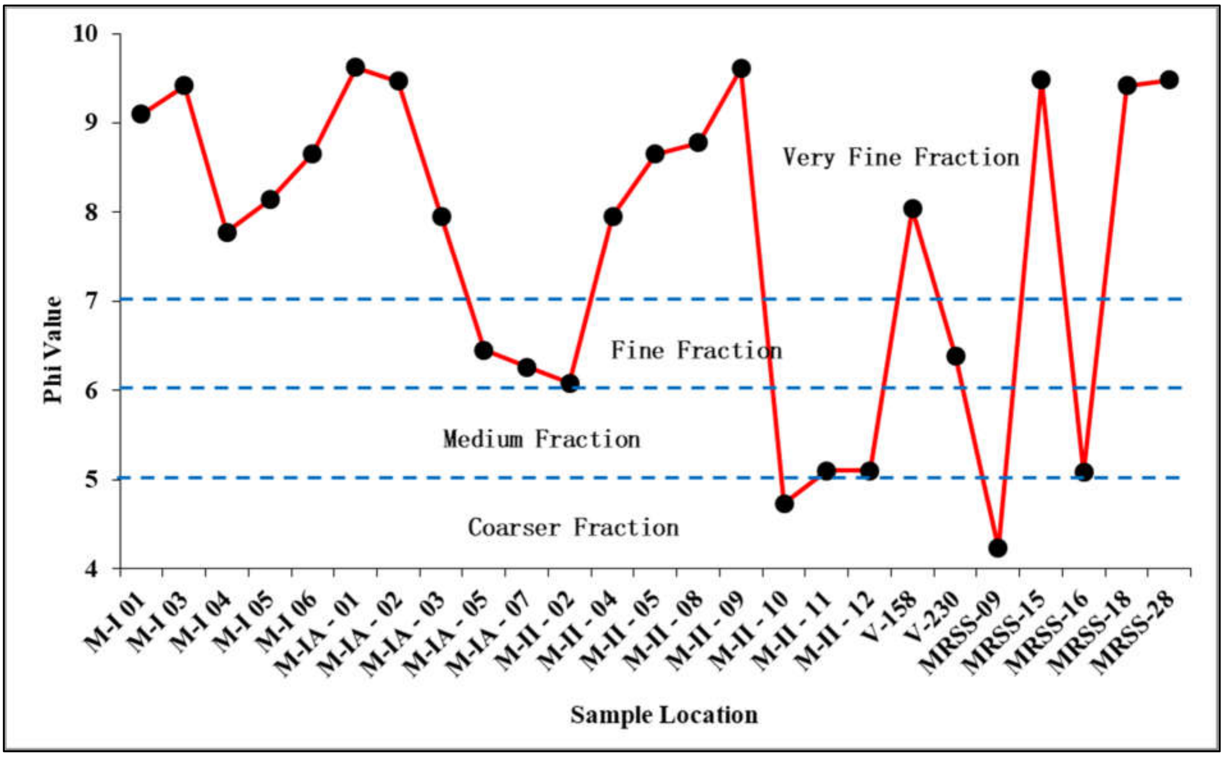

Fig 2 Graphical line plot represents the Graphical Mean of the lignite samples in the study area

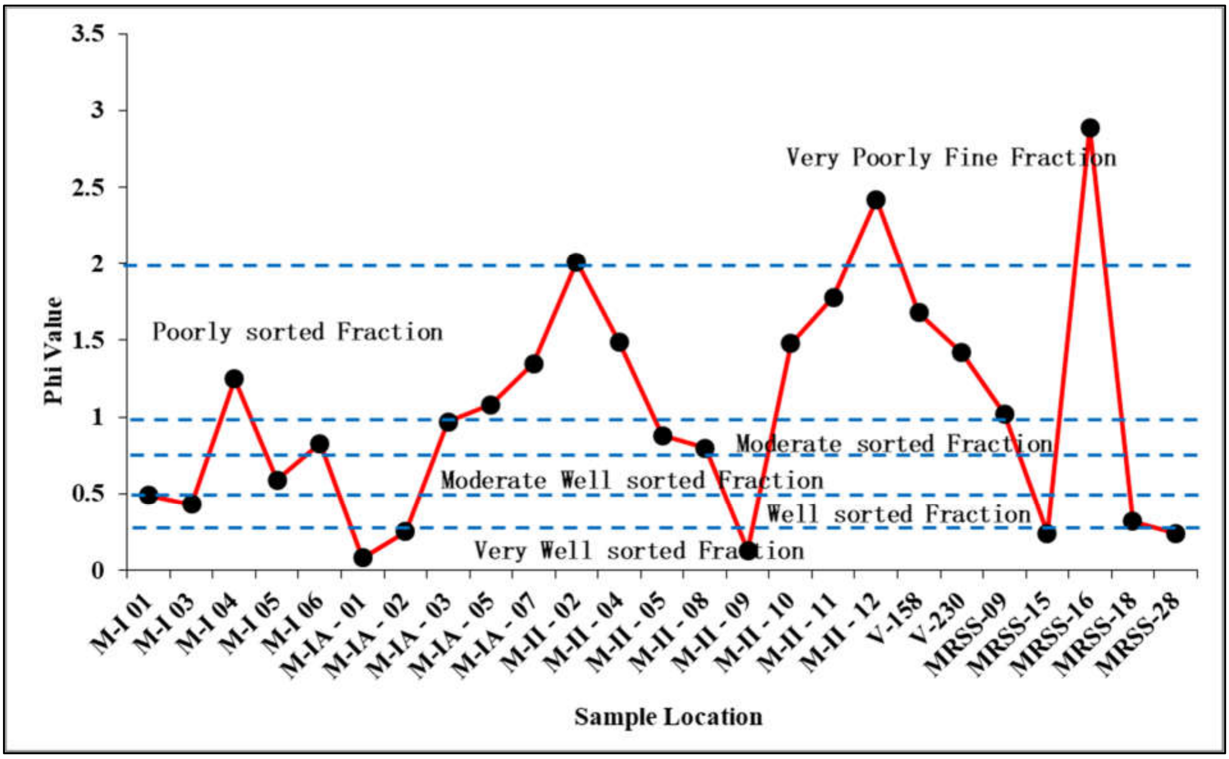

Fig 3 Graphical line plot represents the Graphical Sorting of the lignite samples in the study area

4.3 Graphic Skewness

Graphic skewness is a statistical measure that quantifies the symmetry of particle grain-size distributions. It is calculated using the 16th, 50th, 84th, 5th, and 95th percentiles of the cumulative grain-size curve, following the method outlined by Folk and Ward (1957). This measure helps determine whether a sediment sample is enriched in finer or coarser particles, aiding in the interpretation of depositional processes.

$$SK_I = \frac{(\varphi_{16} + \varphi_{84} - 2\varphi_{50})}{(2(\varphi_{84} - \varphi_{16}))} + \frac{(\varphi_5 + \varphi_{95} - 2\varphi_{50})}{(2(\varphi_{95} - \varphi_5))} \qquad \text{Eqn. 3}$$

The lignite samples from Neyveli block, such as Mine I, indicate values from -0.72 to 0.52; Mine IA ranges from -0.57 to 0.38; Mine II varies from -0.38 to 0.75; Veeranam block shows -0.54 to 0.35; and Sikkal block exhibits -0.58 to 0.77 (Fig 4). From the results, the Neyveli blocks display a very coarse to fine skewed distribution, while Veeranam and Sikkal blocks show a range from very coarse to very fine skewed distributions. Positively skewed particles typically indicate deposition under relatively low-energy conditions. In contrast, negatively skewed distributions suggest particles were transported and deposited under fluctuating or multidirectional currents within a moderately high-energy environment.

4.4 Graphic Kurtosis

Graphic kurtosis is a statistical parameter that describes how peaked or flat grain-size distributions are. It is calculated from the 5th, 25th, 75th, and 95th percentiles of the cumulative grain-size curve, following the method of Folk and Ward (1957). This measure helps determine whether a distribution is sharply peaked (leptokurtic), normally distributed (mesokurtic), or widely spread (platykurtic), providing valuable insights into depositional conditions.

$$K_G = \frac{(\varphi_{95} - \varphi_5)}{(2.44(\varphi_{84} - \varphi_{16}))} \qquad \text{Eqn. 4}$$

The graphical kurtosis of the lignite samples from Neyveli blocks such as Mine I ranges from 0.6 to 2.02. Mine IA varies between 0.66 and 1.02, Mine II shows values from 0.59 to 2.85, and Veeranam block indicates 0.55 to 0.91, followed by Sikkal block ranging from 0.65 to 1.74 (Fig 5). From these observations, Mine I and Mine II indicate very leptokurtic to extremely platykurtic distributions, whereas Mine IA, Veeranam, and Sikkal blocks display very leptokurtic to mesokurtic characteristics. According to Friedman (1962), extremely high or low kurtosis levels suggest that some particles have been classified in a high-energy environment.

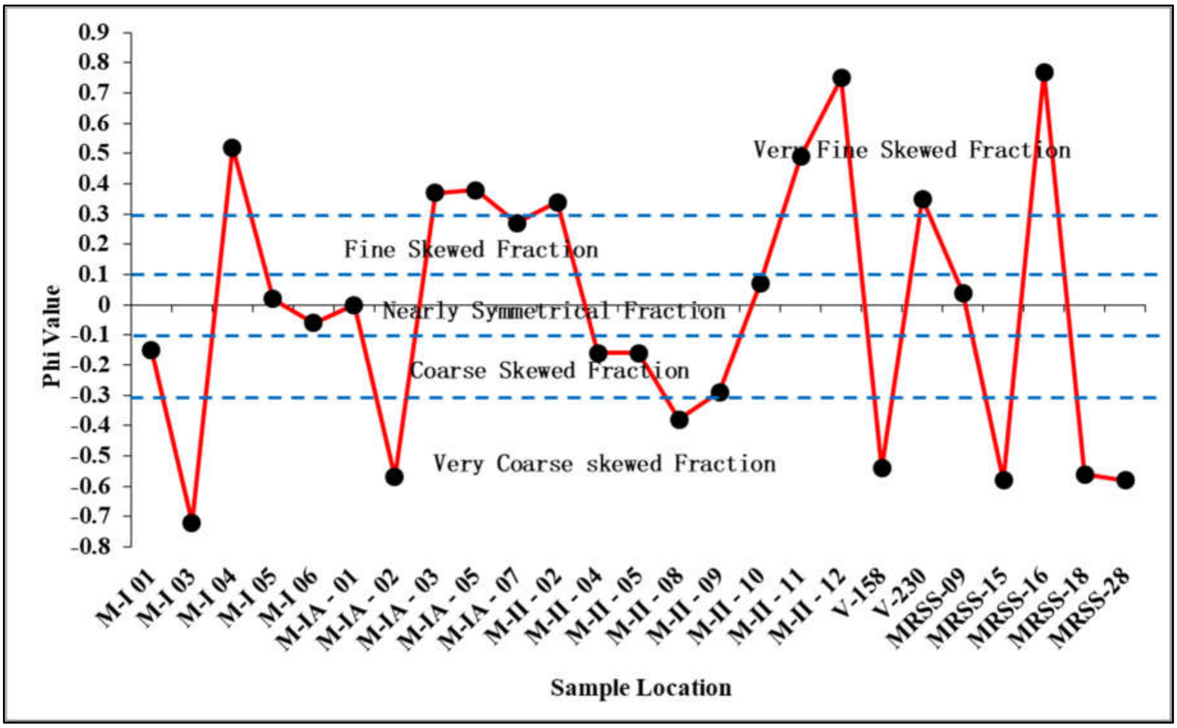

Fig 4 Graphical line plot represents the Graphical Skewness of the lignite samples in the study area

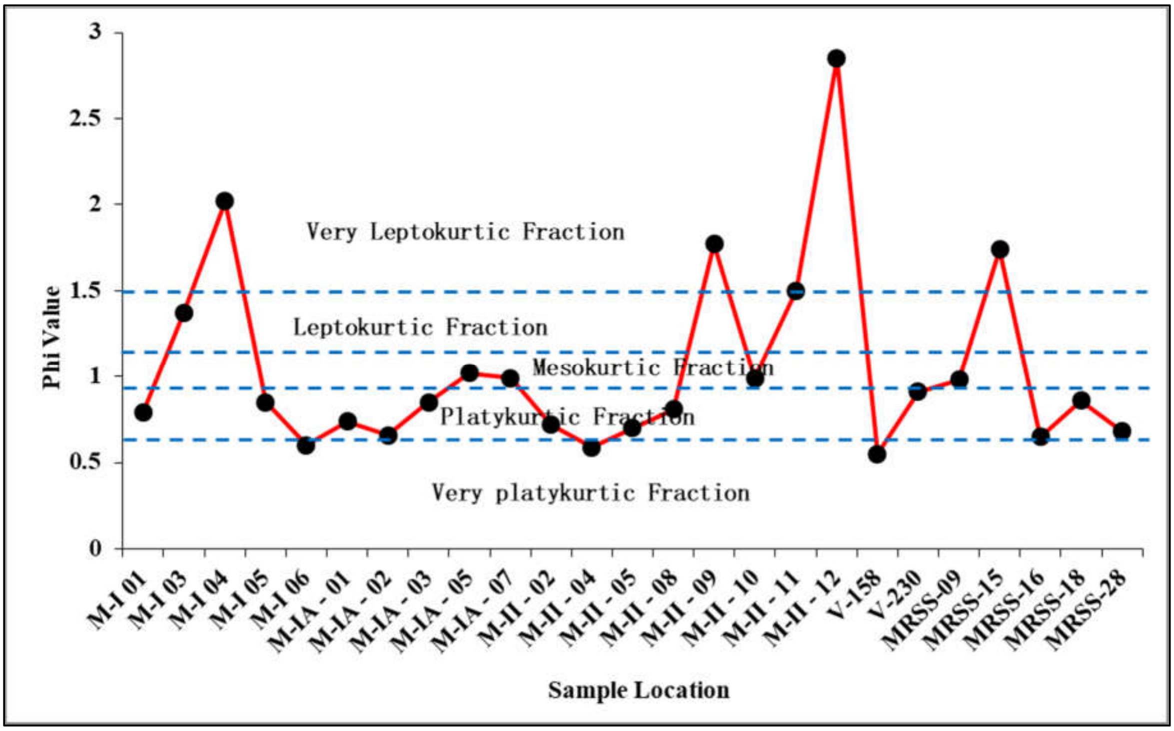

Fig 5 Graphical line plot represents the Graphical Kurtosis of the lignite samples in the study area

5. Conclusion

The present study aims to examine the textural features of lignite samples collected from different zones, including Neyveli block (Mine I, Mine IA, Mine II), Veeranam block, and Sikkal block in southern Tamil Nadu, India. A total of 25 lignite samples were gathered from the study area and analyzed using a particle size analyzer. The textural features were assessed using parameters such as Graphic Mean, Graphic Sorting, Graphic Kurtosis, and Graphic Skewness. Results from Mine I and Mine II in the Veeranam block suggest deposition under moderate to high energy conditions, indicating stronger hydrodynamic influence and more active sediment transport during peat formation. Conversely, Mine IA and the Sikkal block show evidence of low-energy depositional settings, reflecting calmer conditions that favor the preservation of organic material.

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