

Final Report On

**Indigenous Development of NIR
Spectroscope for Instant Prediction
of Coal Quality Parameters**

CMPDI Project code: CP/52

CSIR-CIMFR Project code: GAP-7048/2023-24

Start date: 01/09/2023 Actual End date: 31/08/2024

Revised End date: 31/08 /2025

Project cost: Rs. 1.10 Crore

“Funded under S&T Grant of MoC”

Implementing Agency:

Shri Ramdeobaba College of Engineering & Management, Nagpur

Sub-Implementing Agency:

CSIR-Central Institute of Mining & Fuel Research, Nagpur Research Centre
(Fuel Science Division)

Sub-Implementing Agency-I

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EXECUTIVE SUMMARY

Coal remains India's dominant source of energy, supplying more than 60% of the nation's electricity. The commercial grading of non-coking coal depends on parameters such as Gross Calorific Value (GCV), moisture, ash, volatile matter, fixed carbon and sulphur, all of which are presently determined through laboratory-based chemical analysis. This method is destructive, labour-intensive, and time-consuming, often delaying quality verification during coal dispatch, blending and pricing decisions at mines and thermal power plants. The lack of real-time testing capability continues to be a major operational bottleneck in the coal value chain.

To overcome this limitation, the project investigates a rapid, non-destructive technique for coal quality assessment using NIR/Hyperspectral Imaging (HSI) combined with Convolutional Neural Network (CNN) based modelling. NIR/Hyperspectral imaging captures reflectance values across several hundred wavelengths, enabling coal composition to be inferred from its spectral signature rather than through chemical processing. The objective was to develop a system capable of predicting coal quality parameters instantly from hyperspectral image data, eliminating the need for laboratory testing.

A dataset of more than 11,000 hyperspectral images, captured from coal samples of varying size fractions and chemical characteristics, was used to train the initial deep learning models. After spectral pre-processing and wavelength-band reduction, CNN architectures were trained to predict six coal parameters simultaneously. The final model achieved more than 99% prediction accuracy across all parameters when compared with laboratory-tested values, demonstrating that hyperspectral image-based modelling can match the precision of chemical analysis while operating at significantly lower cost and time.

To evaluate whether the model could be deployed on different imaging systems, a transfer learning phase was carried out using 377 hyperspectral images taken from 72 coal samples using a Holmarc NIR hyperspectral camera. Instead of full retraining, only the upper layers of the original model were fine-tuned, allowing the system to adapt to the new spectral domain. Moisture and ash were predicted directly and used to compute GCV through an empirical formula widely used in the coal industry. The transfer learning results demonstrated practical prediction reliability, with the Mean Absolute Error (MAE) of GCV showing a median error of 262.54 kcal/kg, with most predictions remaining within engineering-acceptable limits. This confirmed that the model trained on one imaging platform could be successfully migrated to another with minimal additional data.

The findings establish that hyperspectral deep learning can replace slow chemical analysis with real-time, image-based coal quality estimation suited for mines, CHP, washeries and power plants. Future work will involve expanding the dataset with more coal samples from additional subsidiaries, developing an indigenous low-cost hyperspectral imaging camera in collaboration with industry, and integrating the trained model into an automated coal grading and dispatch management system.

ABSTRACT

Coal quality assessment plays a crucial role in determining its commercial value and environmental impact. Traditional laboratory-based analysis methods for parameters such as ash, moisture, gross calorific value (GCV), Sulphur, volatile matter, and fixed carbon are often time-consuming and destructive. This study explores a non-destructive alternative by employing hyperspectral imaging (HSI) combined with Convolutional Neural Network (CNN)-based predictive modeling for coal characterization.

Coal samples were collected from Singareni Collieries Company Limited, Telangana, comprising 72 samples and 377 hyperspectral images spanning a spectral range of 300–4,000 nm. Preprocessing and K-Means clustering were applied to enhance the spectral feature representation before feeding the data into a 2D CNN architecture. The model was trained to predict key coal parameters, and performance was evaluated using Mean Absolute Error (MAE) as the primary metric.

Experimental results indicate that the proposed CNN model effectively predicts coal properties, achieving a mean prediction error of approximately 270 for GCV estimation. Further analysis revealed a strong dependency of GCV on moisture and ash content, consistent with established thermochemical principles. This approach demonstrates the potential of hyperspectral imaging and deep learning for real-time, non-destructive coal quality monitoring, offering significant advantages for industrial and mining applications.