



A Comparative Study of Coal Quality: Insights from Actual and Proximate Analysis Models

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Abstract

Coal quality plays a pivotal role in determining its efficiency and environmental impact when used as a fuel source. This study aims to conduct a comprehensive comparison of coal quality by employing two analytical approaches: Actual Analysis and Proximate Analysis. Actual Analysis evaluates the fundamental characteristics of coal, including carbon content, hydrogen, sulfur, and trace elements. In contrast, Proximate Analysis focuses on determining moisture content (TM), ash (ASH), total sulphur (TS), and calorific velocity (CV). By integrating the insights gained from both models, this paper elucidates the strengths and limitations of each method, highlighting their relevance in industrial applications and environmental considerations. The findings provide a nuanced understanding of coal quality, paving the way for more informed decisions in its utilization and management. This study emphasizes the importance of selecting the appropriate analytical method to achieve optimal performance and sustainability in coal utilization.

Keywords: actual analysis; coal quality; comparative study; industrial applications; proximate analysis

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INTRODUCTION

According to Mibei, (2014), coal is a solid hydrocarbon fuel formed through the processes of peating and deposition in swampy basins during geological periods. This involves biogeochemical activities on the accumulation of flora containing cellulose and lignin. Coal is generally classified into four main classes based on ASTM standards, or five if peat is included as the youngest type of coal (Chen et al., 2021; Williams & Hervig, 2004). These classifications are based on proximate analysis, calorific value, ultimate analysis, total sulfur content, and density. Higher ratios of C:O and C:H are found as coal quality increases, with anthracite being the highest quality and lignite the lowest (Mibei, 2014).

The quality of coal is determined through laboratory analyses, including proximate analysis, which measures moisture content, volatile matter, ash content, and fixed carbon, and ultimate analysis, which determines the content of chemical elements like carbon, hydrogen, oxygen, nitrogen, and sulfur. Minerals such as pyrite and macerals may also be present in coal. Evaluating coal quality is crucial for determining its suitability for mining and utilization, aside from considering the amount of coal reserves (Kapugu et al., 2022; Yuan, 2015).

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Chemical elements in coal are divided into organic elements, consisting of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulfur (S), and phosphorus (P), and inorganic elements, which include metals such as silica (Si), aluminum (Al), iron (Fe), calcium (Ca), and magnesium (Mg) (Matsubaya et al., 1973; Tsay et al., 2017; Y. Y. Zhao et al., 2009). Proximate analysis is a fundamental test for determining coal quality, assessing parameters such as moisture content (TM), ash (ASH), total sulphur (TS), and calorific velocity (CV) (Clow et al., 1997; Gan et al., 2017; Lin et al., 2014; Sano & Wakita, 1985; H. Zhao et al., 2020).

Actual and model coal quality analysis involves comparing field data (actual) with drilled well data (model) to evaluate the quality of coal in the pit area against the quality at the time of drilling. Actual Analysis delves into the core attributes of coal, measuring fundamental characteristics such as carbon content, hydrogen, sulfur, and trace elements (Umam et al., 2024). This method provides a detailed understanding of the coal's intrinsic properties, crucial for both industrial applications and environmental considerations (Kasayanond et al., 2019). On the other hand, Proximate Analysis offers a broader overview, focusing on parameters like moisture content (TM), ash (ASH), total sulphur (TS), and calorific velocity (CV). This approach is essential for evaluating coal's usability and performance in various applications (Cole et al., 2023; Williams & Hervig, 2004; Yuan, 2015).

Despite the importance of both methods, there is a need for a comprehensive comparison to highlight their respective strengths and limitations. This study aims to bridge this gap by integrating insights from Actual and Proximate Analysis models, offering a nuanced perspective on coal quality. The findings will inform stakeholders in the coal industry, enabling more informed decisions regarding coal utilization and management.

By understanding the intricate differences between these analytical methods, we can optimize the use of coal resources, enhance energy efficiency, and minimize environmental impact. This paper sets the stage for a deeper exploration of coal quality, contributing to the sustainable and responsible use of this vital energy source.

METHOD

Data collection

Coal samples for this study were collected from various mining sites (PT. Artha Tunggal Mandiri (ATM) Gunung Tabur region, Berau district, East Kalimantan, Indonesia) to ensure a diverse representation of coal quality in January-March 2024. Samples were taken from surface and subsurface layers to account for variations in geological formation and mining methods. Data collection is a stage where after the maturation of the concepts and equipment in this study, where the data taken is in the form of taking coal samples, analyzing data in the laboratory and taking model data using GEOVIA Minex.

Literatur studies

Literature study is a data collection technique carried out by researchers by examining theories, opinions and points of thought contained in social media, as well as books, especially journals that support and are relevant to the problems discussed in the research.

The method carried out in this study is a quantitative method. There are several stages for data collection to data processing **Figure 1**, which includes:

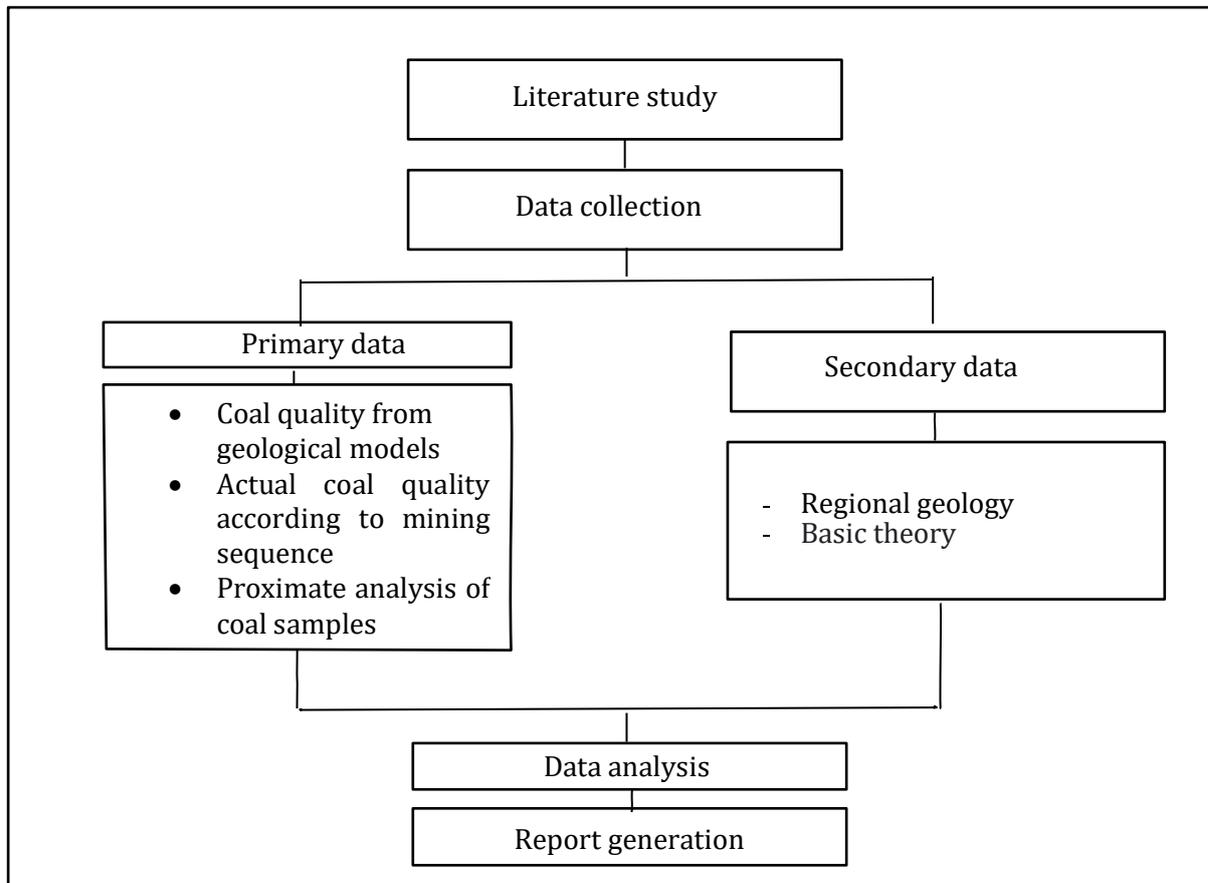


Figure 1. Flow chart of research methods

Primary data

Primary data is a source of research data obtained directly from the original source (not through intermediary media). The primary data from this study include the quality of coal from geological models, the actual quality of coal according to the mining sequence, and the analysis of coal quality proximation.

Secondary data

Secondary data is data obtained or collected by people who conduct research from existing sources. This data is used to support primary information, where this data can be obtained from library materials, literature, previous research, books, and so on. The secondary data from this study includes regional geology as well as theoretical basis.

Data analysis

Data analysis is carried out using software, data from research or from the field that can be processed using software, in the form of, GEOVIA Minex, and excel. The data from the study are in the form of actual coal quality and model coal quality. Actual and model Coal quality starts from January-June.

Actual Analysis

Actual Analysis was conducted to determine the fundamental characteristics of the coal samples. The following procedures were employed:

1. Carbon, Hydrogen, and Nitrogen Content: Elemental analysis was performed using a CHN analyzer to measure the carbon, hydrogen, and nitrogen content of the coal samples.
2. Sulfur and Trace Elements: Sulfur content was determined using a LECO sulfur analyzer. Trace elements were analyzed using inductively coupled plasma mass spectrometry (ICP-MS).

3. Moisture Content: Moisture content was measured by drying the samples in an oven at 105°C until a constant weight was achieved.

Proximate Analysis

Proximate Analysis was carried out to evaluate the general composition of the coal samples. The following procedures were used:

1. Moisture Content: Similar to Actual Analysis, moisture content was determined by drying the samples at 105°C.
2. Volatile Matter: Volatile matter content was measured by heating the coal samples in a covered crucible at 950°C for seven minutes.
3. Ash Content: Ash content was determined by combusting the coal samples in a muffle furnace at 750°C until a constant weight was achieved.
4. Fixed Carbon: Fixed carbon content was calculated by subtracting the sum of moisture, volatile matter, and ash content from 100%.

To validate the accuracy and reliability of the analytical methods, duplicate samples were analyzed, and the results were compared. Quality control measures, including the use of certified reference materials, were implemented throughout the study.

RESULTS AND DISCUSSION

Coal quality analysis was carried out in the laboratory of PT. Artha Tunggal Mandiri (ATM) refers to the American Standar of Testing and Material (ASTM) and the company standard of PT. Artha Tunggal Mandiri (ATM). The following are the parameters analyzed from Total moisture, Ash content, Total sulphur, and Caloric velue ar. Coal quality analysis from January to June includes seam C, D, and E.

Comparative analysis of actual and model Coal quality

The results of the Coal Quality Analysis in actual have a not significant comparison with the quality of the Coal model. The approach taken includes looking at the results of proximate analysis of the value of moisture content (TM), ash (ASH), total sulphur (TS), and calorific velocity (CV). Compare the results of the calculation of actual coal quality parameters with model coal quality parameters in January-March.

Actual coal quality and model in January-March 2024

From **Table 1**, it can be seen that the actual difference values with the January-March model of each parameter are not so significant, moisture content (TM) 0.2-1.59 (% ar), ash (ASH) 0.76-5.01 (% adb), total sulphur (TS) 0.1-0.6 (%adb), calorific velocity (CV) 4-151 (kcal/kg).

Table 1. Coal quality in January-March 2024

Month	Seam		Quality			
			TM (% ar)	ASH (% adb)	TS (% adb)	CV (kcal/kg)
January	C	model	38,67	5,18	0,14	3787
		actual	37,09	7,97	0,19	3752
		difference	1,58	2,79	0,05	35
	D	model	39,18	4,35	0,19	3814
		actual	39,16	6,60	0,20	3669
		difference	0,02	2,25	0,01	145
February						

C	model	38,55	5,44	0,14	3776
	actual	39,15	3,98	0,13	3792
	difference	0,6	1,46	0,01	16
D	model	39,08	4,08	0,16	3830
	actual	38,92	5,28	0,17	3776
	difference	0,16	1,2	0,01	54
E	model	39,19	8,98	0,19	3641
	actual	37,83	13,99	0,24	3713
	difference	1,36	5,01	0,05	151
March					
C	model	38,57	5,48	0,14	3775
	actual	39,64	3,47	0,11	3771
	difference	1,07	2,01	0,03	4
D	model	39,22	4,19	0,17	3823
	actual	39,67	4,95	0,15	3718
	difference	0,45	0,76	0,02	105
E	model	39,19	8,98	0,19	3643
	actual	37,6	11,07	0,25	3550
	difference	1,59	2,09	0,06	93

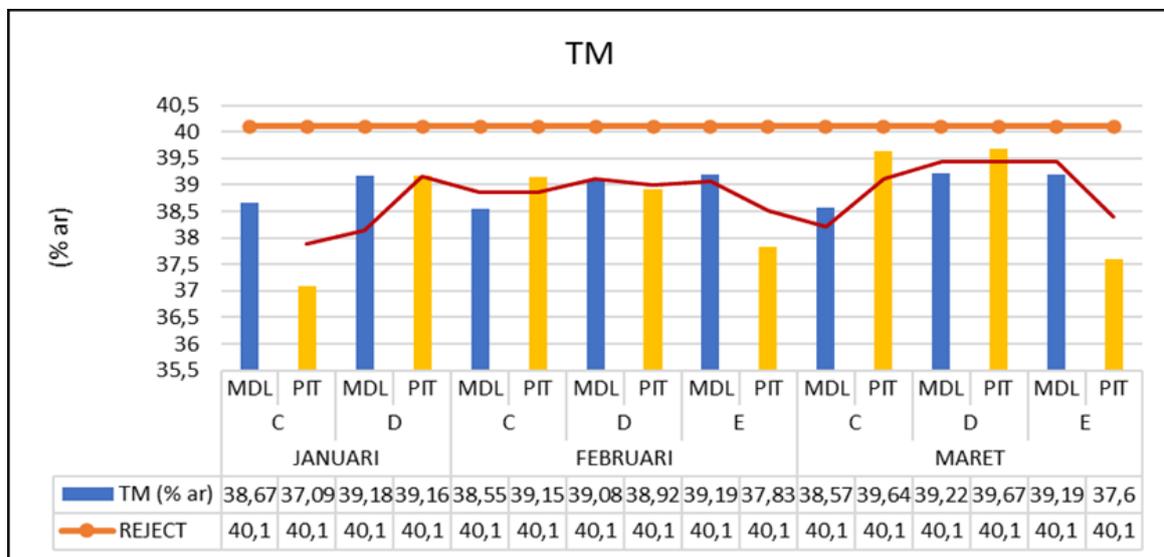


Figure 2. . Graph of total moisture content (TM) values in January-March 2024

Based on **Figure 2**, the comparison of the total moisture (% ar) of actual coal with the total moisture (% ar) of the model coal in January-March with 3 samples of seam, namely seam C, D and E, there is a difference between 0.6 - 1.59 (% ar). The highest actual total coal moisture value is seam D in March with a baseline value of 39.67 (% ar). The total moisture value in the D semester in March is the highest of all the existing semester in the months of Janauri, February, and the C and E semesters in March, but it is still below the standard of the total moisture value that has been set by the company, which is 40.1 (% ar). The total moisture content of seam D in March increased due to waterlogging in the seam D area as shown in **Figure 3**.



Figure 3. Waterlogging in Seam D in March

Based on Figure 4, the comparison of the Ash content (% adb) of actual coal with the Ash content (% adb) of model coal in class I with 3 sempel seam, namely seam C, D and E, there is a difference value of 0.76-5.01 (% adb). The highest actual coal Ash content value in January-March is seam E in February with a value of 13.99 (% adb). This value has passed the Ash content value standard set by the company, which is 10 (% adb). The Ash content value in February E rose from model to actual due to the contamination with the coal roof as shown in Figure 5. The contamination occurs when rain and water bring the roof to flow through the coal front and coal cracks (cleats) so that there is an increase in Ash content as well as an increase in total moisture .

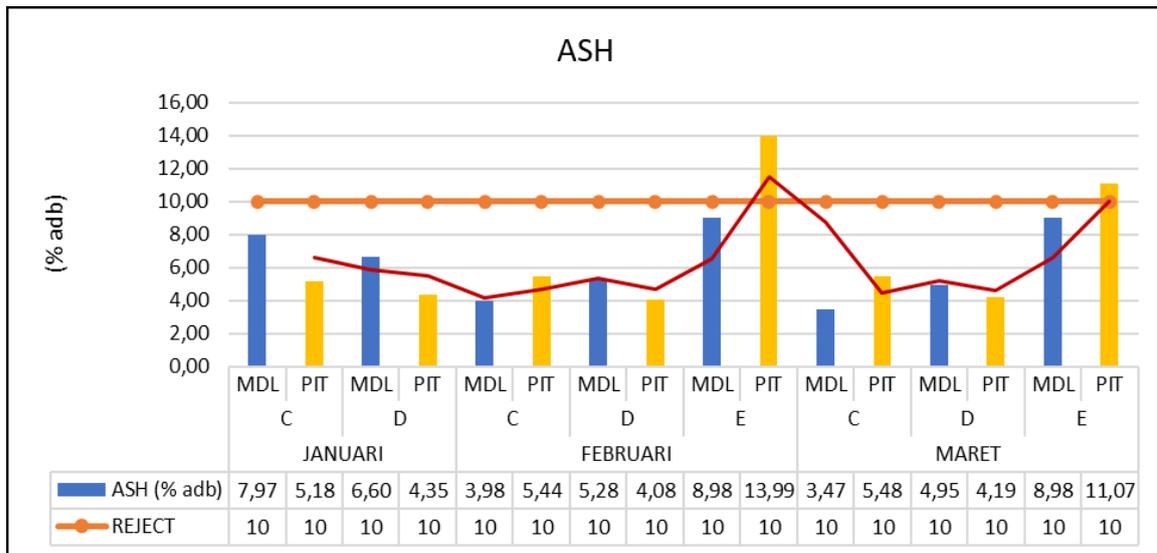


Figure 4. Graph of ash (ASH) content value in January-March 2024

Based on Figure 6, the comparison of the total sulphur (% adb) of actual coal with the total sulphur (% adb) of model coal in January-March with 3 sempel seam, namely seam C, D and E, there is a difference value of 0.1-0.6 (% adb). The highest actual total coal sulphur value in January-March was found in the E semester of March, which was 0.25 (% adb). Although this value is the highest of all seam in January-March, it is still below the standard of the total sulphur value that has been set by the company, which is 0.60 (% adb). The total sulphur value in seam E in March increased from model to actual, because in seam E there was contamination with surrounding rocks containing sulphur levels as shown in Figure 7.



Figure 5. Controversy between E seam coal and coal roof in February 2024

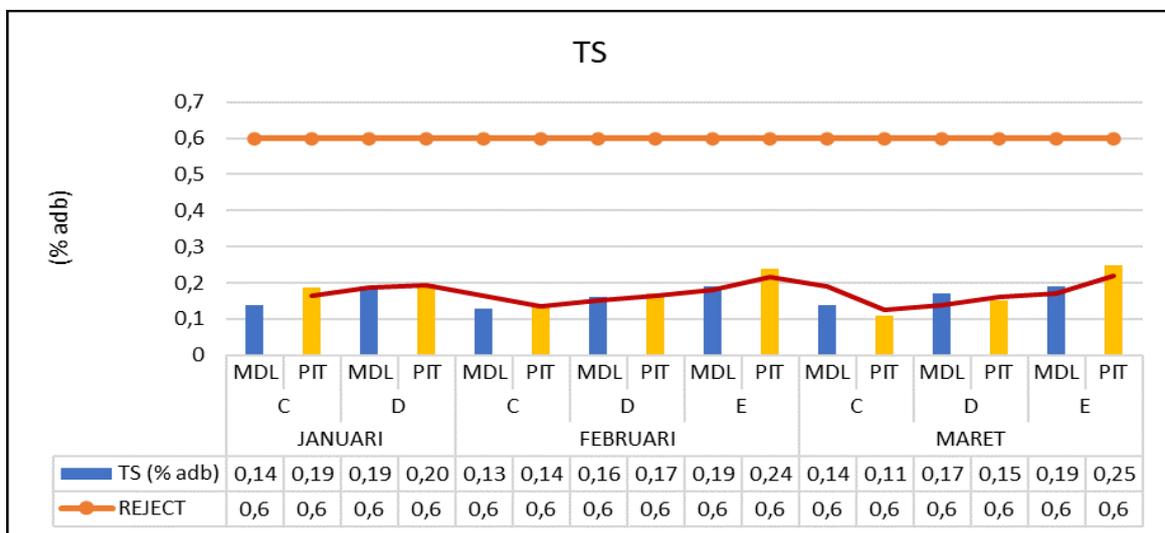


Figure 6. Graph of total total sulphur (TS) value in January-March 2024

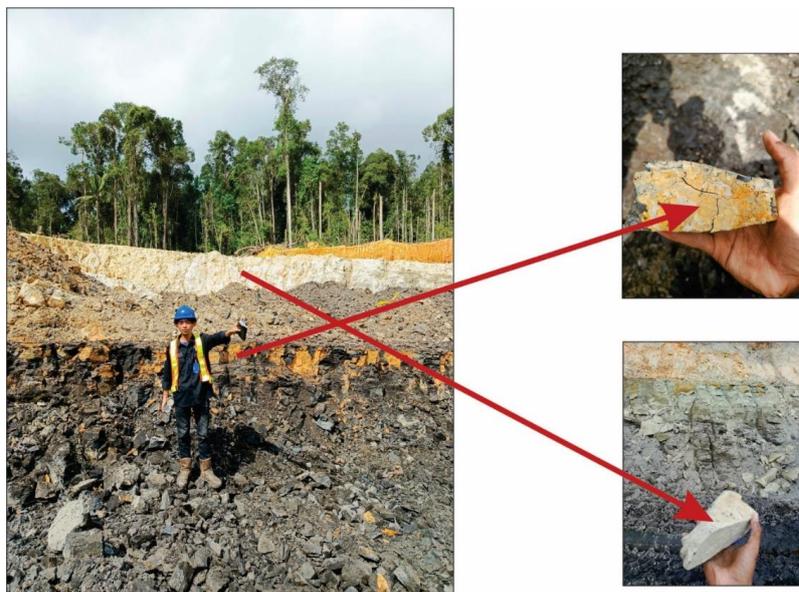


Figure 7. The contannity between seam E coal and surrounding rocks containing sulfur, in March 2024

Based on **Figure 8**, the comparison of the Calorific value (kcal/kg) of actual coal with the Calorific value (kcal/kg) of model coal in January-March with 3 samples of seam, namely seam C, D and E, there is a difference value of 4-145 (kcal/kg). The highest actual calorific value of coal in class I was found in seam C in February, which was 3792 (kcal/kg), and the lowest calorific value in class I was found in seam E in March, which was 3550 (kcal/kg). When compared to the Calorific value of coal in the model, the low actual Calorific value of coal occurs due to the high value of Total moisture and Ash content. The lowest Calorific value in January-March, namely Seam E in March, has passed the Calorific value set by the company, which is 3600 (kcal/kg).

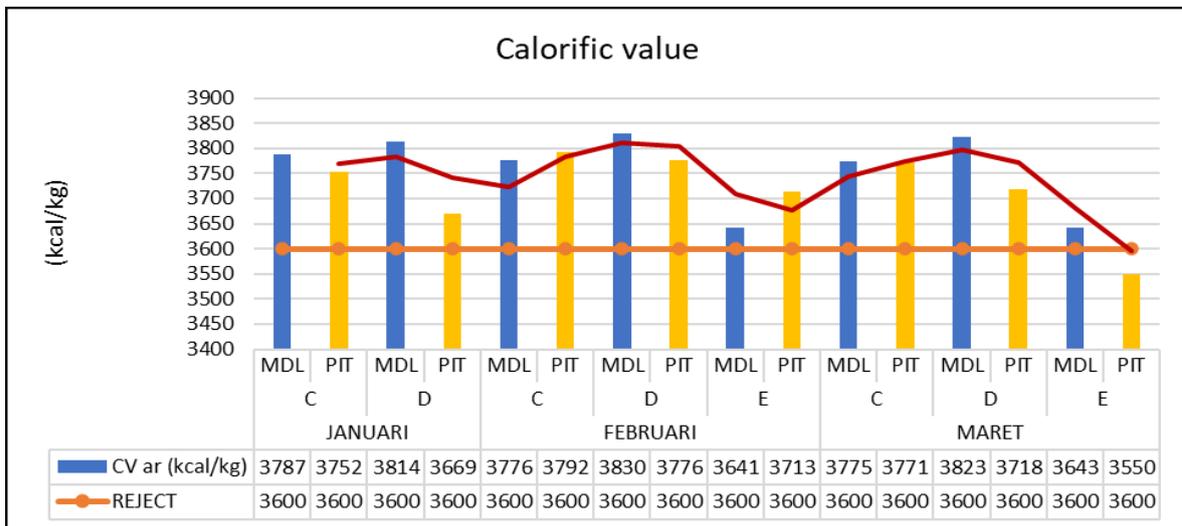


Figure 8. Graph of calorific velocity value in January-March

CONCLUSION

Field observations and data analysis revealed several key conclusions. The study identified discrepancies between actual coal quality and the modeled coal quality during January to March, with variations observed in total moisture (0.6 - 1.59% ar), ash content (0.76 - 5.01% adb), total sulfur (0.1 - 0.6% adb), and calorific value (4 - 145 kcal/kg ar). These differences can be attributed to factors such as coal contamination from roof materials and waterlogging in the coal front area. The findings provide a nuanced understanding of coal quality, paving the way for more informed decisions in its utilization and management. This study emphasizes the importance of selecting the appropriate analytical method to achieve optimal performance and sustainability in coal utilization.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest concerning the publication of this article. The authors also confirm that the data and the article are free of plagiarism.

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