



ADDIS ABABA INSTITUTE OF TECHNOLOGY
CENTER FOR ETHIO-MINES DEVELOPMENT
MASTER OF DEGREE IN MINERAL ENGINEERING

Determination of Coal Rank and Operational Efficiency through Blending Techniques in the ET-
Coal Washing Plant in Dawuro, Ethiopia

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Approval Sheet

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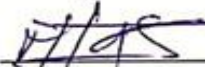
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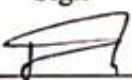
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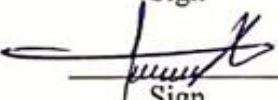
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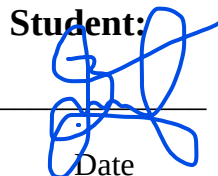
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Declaration of Originality

I hereby affirm that this project is my original work for the completion of my Master's degree, conducted under the supervision of Dr. Bisrat Kebede and Dr. Bekele Ayele, at, Addis Ababa University, Addis Ababa Institute of Technology, during the academic year 2025. Furthermore, I declare that this project has not been submitted to any other university, organization, or institution for the award of any degree or diploma.

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Abstract

The study investigates the impact of blending and subsequent washing and flotation processes on coal quality. Four raw coal samples sourced from different seams were blended to create a uniform feed before undergoing flotation. The study provides laboratory results of coal samples before and after blending, washed by ET- Washing plant, and flotation treatments, highlighting significant improvements in key quality parameters, such as calorific value, ash content, sulfur levels, moisture content, and volatile matter. The flotation process, in particular, demonstrated considerable advantages in reducing ash and moisture content while increasing calorific value, making the coal more suitable for energy production. However, challenges related to sulfur content and volatile matter remain. Additionally, environmental concerns such as water contamination, air pollution, and solid waste management were addressed, with recommendations for the implementation of flotation circuits, desulfurization, and efficient waste management practices to minimize environmental impact. Economic analysis of the plant's operation, including capital and operating costs, demonstrated that while the current process is cost-effective, the addition of flotation could enhance coal recovery and overall revenue. The study concludes that flotation provides the most significant improvements in coal quality and efficiency, making it a viable option for enhancing the plant's overall operational and economic performance.

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Acronym

American Society for Testing and Materials: ASTM	5
Degree Celsius: °C	17
Dense media cyclone: DMC	19
East: E	5
Gram: g	17
Kilo-calories per kilogram: kcal/kg	22
kilometer: km	2
kilowatt-hours per ton: (kWh/t)	21;
meters above sea level: masl	3
North: N	5
Overflow: O/F	19
<u>Percent: %</u>	24
Sulfur dioxide: SO ₂	8
Underflow: U/F	19
Washing Efficiency: We	21
Water: H ₂ O	20

CHAPTER ONE

INTRODUCTION

1.1 Background

Coal is a natural mineral resource formed by the accumulation of vegetable matter. Most coal seams were formed over 300 million years ago through the decomposition of vegetable matter from dense tropical forests that once covered certain areas of the Earth (Wills et al., 2006). During the early formation of coal seams, the rotting vegetation formed thick beds of peat, an unconsolidated product of vegetation decomposition, found in marshes and bogs (Wills et al., 2006).

The primary coal deposits are found in the Inter-Trappean geological formation, with the maximum thickness of coal reaching 4 meters and coal-bearing sediments reaching up to 300 meters. The best coal deposits are found in sandstone-coal-shale and mudstone-coal-shale facies. Based on proximate analysis and calorific value data, Ethiopian coals are categorized as lignite to highly volatile bituminous coal. The country has an estimated total coal reserve of about 297 million tons, which can be considered a significant alternative energy source (Wolela, 2007).

Coal's physical and chemical characteristics are highly variable, and these properties influence nearly every operational aspect of a power plant, including forced outages, maintenance costs, auxiliary power needs, heat rate, emissions, and the ability to meet full load. However, over time, coal availability and affordability may change, and plants may need to consider using coals that differ from those they were originally designed for. Given that coal characteristics impact almost all areas of plant operation, it's essential to predict the physical and economic challenges that may arise when switching coals. Coal blending, at its core, is the practice of mixing available coals to produce a blend that combusts efficiently to generate heat and/or power (L L Sloss, 2014).

Energy is a vital resource for various sectors, including industry, agriculture, mining, construction, and services, and it plays a crucial role in a nation's economic development. While global oil reserves are expected to last for about 40 more years and natural gas for around 60 years, proven coal reserves could last for 200–300 years at the current consumption rate. The optimization of coal blending in the coal preparation process is a critical aspect of coal quality control, ensuring the production of high-quality products in coal preparation plants (Wolela, 2007).

Coal blending optimization of coal preparation production process is one of the most important segments in the schedule of coal preparation production, and the last link of quality control to

ensure good products in coal preparation plant. It can increase the diversity of prepared coal, quality stability and the flexibility of production (Xi-jin et al., 2009a).

1.2 Statement of the Problem

For coal producer's company and country coal blending offers many advantages. Coals can be bought on the spot market for a bargain price and then blended with higher cost coal can produce a saleable coal with profit. In some cases, coals are unsaleable without blending and so an otherwise useless coal upgraded to a valuable product through blending (L L Sloss, 2014).

The coal processing industry faces significant challenges that impact efficiency, product quality, and environmental compliance. As the demand for high-quality coal increases, the variability in feed quality from different sources complicates the production process. Current blending and washing operations often fail in Ethiopia and meet the demands of market standards due to inadequate methodologies and outdated technologies (Jyothi & Parhi, 2021). Few of the coals are washed and the handling of the coals tends to be relatively basic at some plants. Moisture can cause distinct problems with both coal handling and plant performance, especially during the rainy season. The majority of these plants have been designed to handle dry lumped coal and so changes in coal characteristics can lead to problems. During the rainy season, wet coal can cause disruption to the flow of coal from stockpiles to the plant, in turn leading to capacity dips and decreased performance (L L Sloss, 2014).

1.3 Objective of the Study

The main objectives of the study is to enhance the overall efficiency and quality of coal processing operations by optimizing feed quality, blending techniques, and washing processes, thereby improving product consistency, reducing environmental impact, and meeting market demands

1.3.1 Specific Objectives

- To improve Feed Quality: Analyse the characteristics of coal received from various sources to identify quality discrepancies implement quality control measures to ensure consistent feed quality that meets industry standards.
- Optimize Blending Techniques: Develop and implement predictive models for blending different coal grades to achieve optimal quality and performance. Utilize real-time data analytics to adjust blending processes dynamically, ensuring uniformity in product quality.

- To optimize operational efficiency: Enhance operations by implementing flotation circuits and systems to optimize productivity, reduce waste, lower costs, and minimize resource usage.

1.4 Significance of the study

This research project is significantly help the plant owner and country, as it is provide valuable information that can be used to improve the economic viability of coal mining operations and process operation in Ethiopia. The coal plant not only enhances its productivity and profitability but also contribute positively to the local community, investor's regional, environmental impact assessment and country as a whole. The finding of this study has help to increase the efficiency of coal processing operations, reduce costs, and increase revenue for the country.

1.5 Scope of the study

This study covers the technical factors (such as coal rank and blending), the operational efficiency (performance of the plant), and potentially examines environmental or economic issues related to the ET-Coal washing process in Dawuro, Ethiopia.

1.6 Study Area

1.6.1 Location

The study area is located in the Dawuro Zone with in the Southwest Region, around 500km southwest of Addis Ababa, the capital of Ethiopia, and about 111 km west of Wolaita Sodo, Dawuro is bordered on the south by Gofa Zone, on the west by the Konta Zone, on the north by the Gojeb River which defines its boundary with the Oromia Region, Jimma zone, on the north-east by Hadiya and Tembaro Special Woreda in Central Ethiopia Regional State, and on the east by Wolayita Zone; the Omo River defines its eastern and southern boundaries.

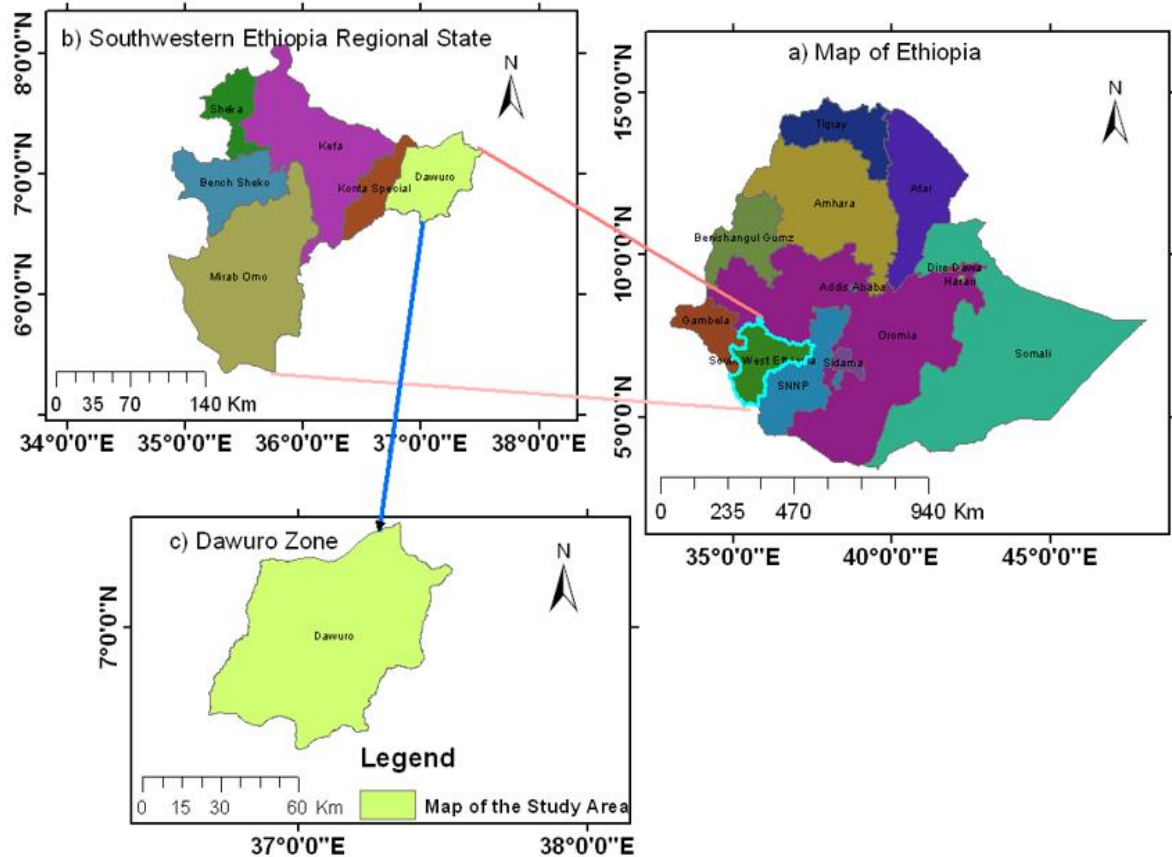


Figure 1: Location map of study area

1.6.2 Climate and Physiography of the study area

Climate: the altitude variations contribute to a range of climatic conditions within Dawuro Zone. The average annual temperature spans from 15.1°C in the highland areas to 27.5°C in the low-land regions. This climatic diversity supports a variety of natural vegetation and forest types, including the Churuchura-Chabara National Park and forests along the Gojeb and Omo river valleys. However, the region faces challenges related to climate change, with farmers in districts like Mareka and Essera reporting changes in temperature and precipitation patterns, affecting their agricultural practices (Aushecho, 2025).

Physiography: the zone's terrain is characterized by significant elevation changes, ranging from approximately 500 meters above sea level (m.a.s.l.) in the lower Omo River valley to about 3,600 m.a.s.l. in the highlands of Dita. This variation results in a landscape of mountains and dissected plateaus, indicative of a complex geological history. Notable high points include Atto, Issera, Umbuti, and Sadam. The presence of rivers such as the Omo and Gojeb further enriches the zone's topography (Asrat, 2018).

CHAPTER TWO

LITERATURE REVIEW

2.1 Coal Geology

Dawuro coal seam is the geographic location with coordinates 280000-305000E and 774000-797800N primarily found northeast and southeast of Tercha. These seams appear irregularly in large areas and cover a limited area. An impure coal layer of about 0.8 m thick is inter-bedded with a thin layer of carbonaceous mudstone identified in the Bachire stream. This coal transitions laterally into carbonaceous mudstone and eventually terminates, covered by a thick layer of soil. Geometrically, the coal layer is lenticular, localized, and not laterally persistent. The coal in this area falls within the Lignite to High Volatile Bituminous rank category as per the American Society for Testing and Materials (ASTM) classification scheme (Genetu & Kebede, 2024).

2.2 Regional Geology

The Ethiopia landscape features vast plateaus in the northwest and southeast, the central Ethiopian Rift Valley, and the Afar Depression (Asrat, 2018). On the edge of the southwestern Ethiopian Plateau, the main Ethiopian Rift contains a thick sequence of flood basalts with alkaline to tholeiitic characteristics, along with some minor rhyolites, which were deposited from the Eocene to the Middle Miocene (Wolela, 2007). The Dilbi-Moye and Gojeb-Chida Basins, along with several smaller grabens on the southwestern plateau containing coal and oil shale deposits, formed as a result of the structural development of the western branch of the African Rift System. These grabens were likely influenced by the NNE-SSW/NS trending Ashange rift, which is the northern extension of the western rift (Abebay et al., 2024). The Jimma map sheet highlights the Tarcha area, where Omo trachyte flows are visible in the valley of the Omo-Gibe River basin. This basin stretches from Kenya into Ethiopia and lies between major rift systems, including the main Ethiopian Rift, the Chew Bahir Rift, and the Lake Turkana Rift (Abebay et al., 2024). The basin's geological composition consists of a Precambrian crystalline foundation, Tertiary volcanic rocks, Quaternary alluvial deposits, and volcanic flows (Gezahegn & Getaneh, 2020). The Cenozoic rocks in southwestern Ethiopia offer evidence of both pre-rift and post-rift sequences. The region is largely covered by Tertiary lava flows, pyroclastic flows, fallouts, ash flows, along with some Quaternary ashfalls and alluvial deposits (Guijian et al., 2006).

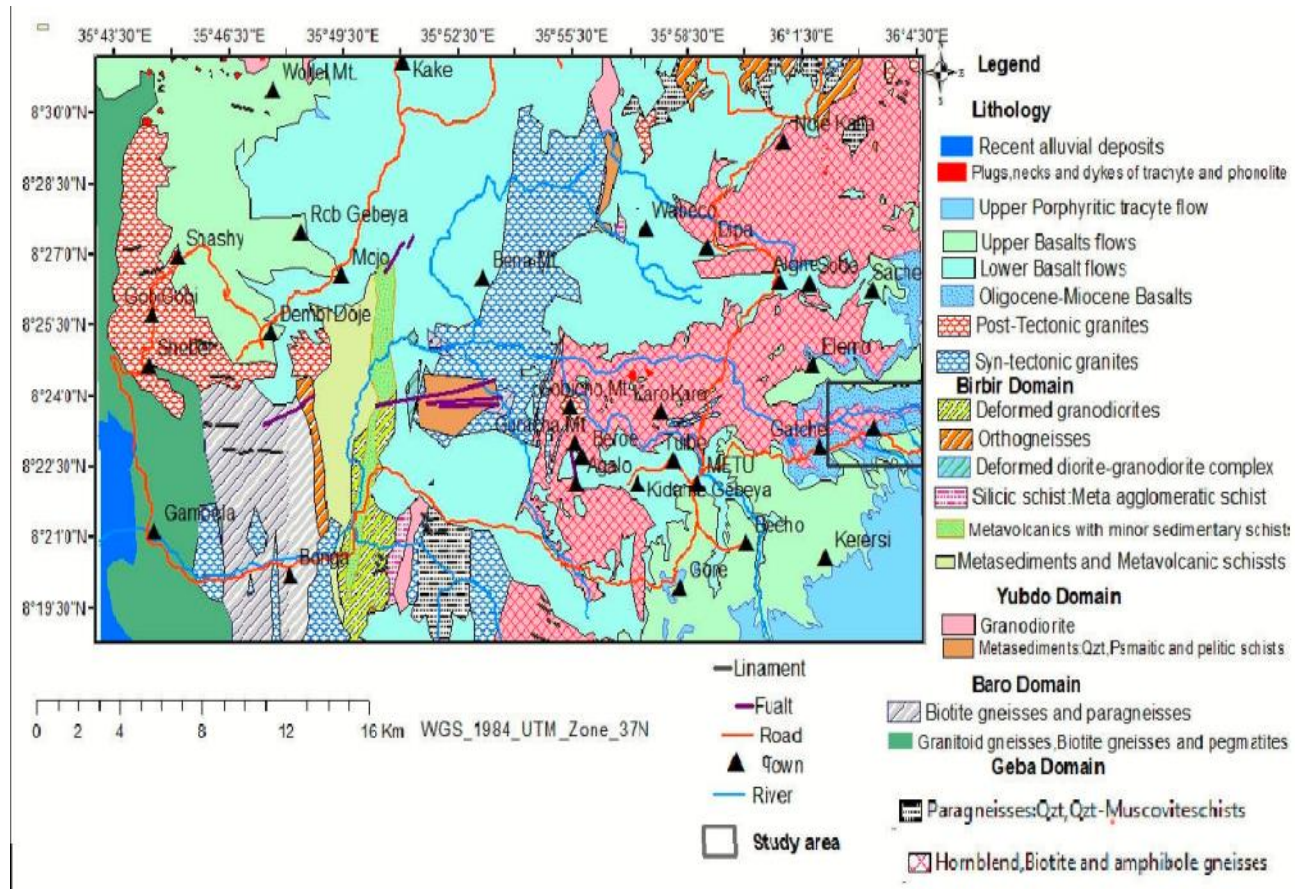


Figure 2: Regional Geological map of South Western Ethiopia (After Mengesha , 1996)

2.3 Local Geology

Dawuro-Tercha is a subsheet within the Jima map sheet. Geologically, it is primarily covered by trachyte flows, which are exposed in the Omo River Valley in the eastern part of the study area. These trachyte flows can also be seen in the Gojeb River Valley near Chebera Churchura National Park, south of Felega Selam, southwest of the map area, and in the Wuki Bro-Gera lowlands, which contain coal layers north of Chida. East of Tercha and west of Gojeb town, the unit is mixed with weathered ignimbrite, which appears light gray and has a medium-grained texture. Northwest of Chida, this lower trachyte flow is interlayered with horizontal, often brittle coal beds (Abebay et al., 2024).

Trachyte- This unit spans the uppermost layers of the coal quarries near the Baccire River. The material is fine to medium-grained and massive, appearing light gray when weathered and dark gray when fresh. Its thickness varies from 2 to 7 meters. The coal-bearing sediments are unevenly distributed, forming horizontal layers, with a total thickness that does not exceed 30 meters. Most of the coal and coal-bearing sediments are found as surface deposits.

Mudstone – The majority of sediments in the study area are surface deposits. The mudstone is fine- to medium-grained, varying from friable to compact, and forms horizontal layers that typically break into small blocks.

Shale – This material is distinguished by its gray color, high friability, and fine-grained texture, and is found above the intercalated coal. The shale varies from fissile to compact units, forming horizontal layers, and is highly prone to sliding due to closely spaced fractures.

Coal – The coal found in the study area is characterized by a light to dark color and is typically located at the base of slope sections, where it is weaker in strength. These quarry sites show vertical and sub vertical fractures, as well as lamination and bedding within the coal seam.

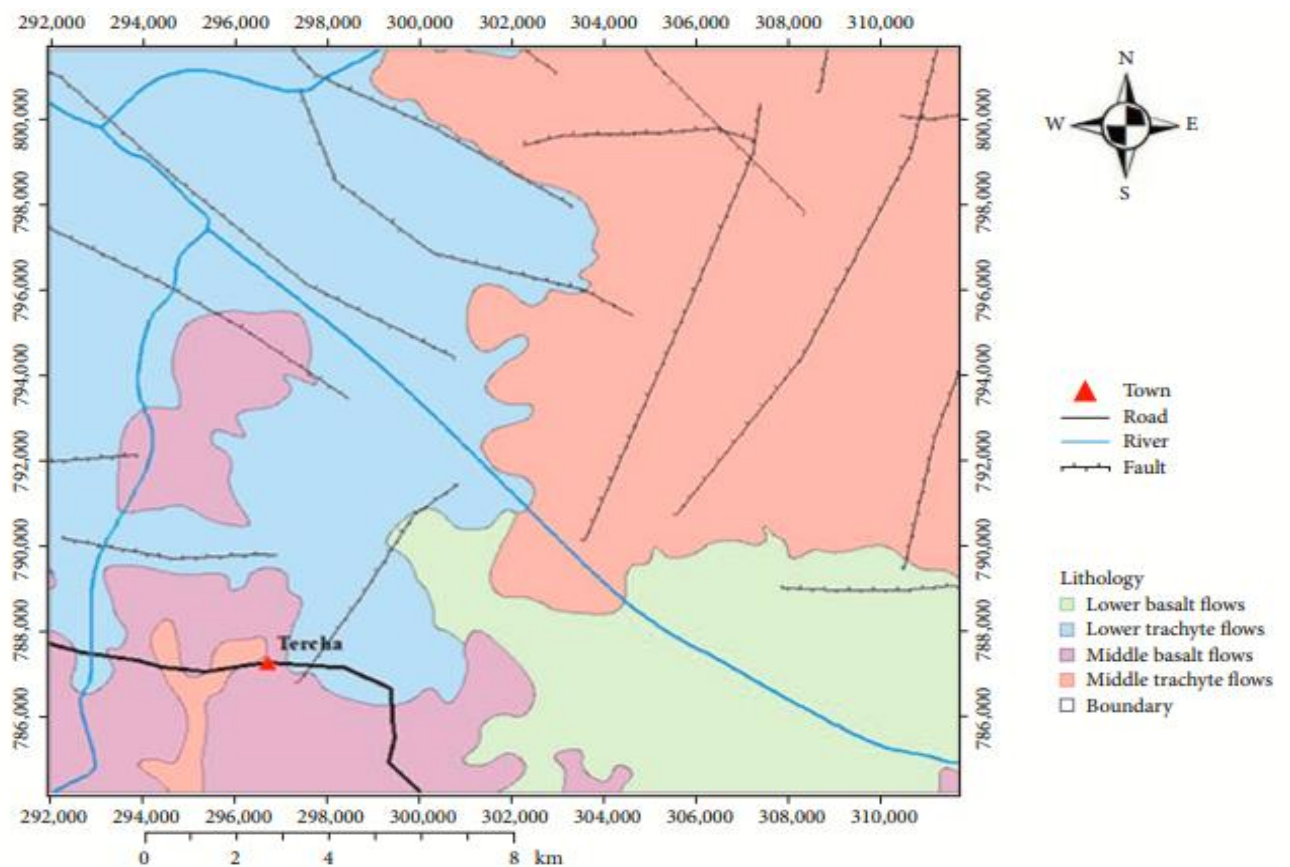


Figure 3: Local geology of the study area (Ababay et al., 2024)

2.4 Coal Processing

Coal preparation is an integral part of the coal commodity supply chain. This stage of post-mining, pre-utilization beneficiation uses low-cost separation technologies to remove unwanted mineral matter and moisture which hinder the value of the coal product. Coal preparation plants typically employ several parallel circuits of cleaning and dewatering operations, with each circuit

designed to optimally treat a specific size range of coal. Recent innovations in coal preparation have increased the efficiency and capacity of individual unit operations while reinforcing the standard parallel cleaning approach (Noble & Luttrell, 2015a).

2.5 Importance of Coal Processing

Coal preparation is a stage in the coal supply chain that follows mining but precedes shipment to the final end user. For many operations, run-of-mine coal consists of a composite mixture of carboniferous material and various non-coal impurities, such as rock, shale, clay, and water. Coal preparation, also denoted washing, cleaning, processing or beneficiation, is the stage where invaluable impurities are physically separated from the coal material in order to satisfy the specifications set by a given coal market. Coal has two primary final end uses: (1) thermal (steam) coal used to generate electricity, and (2) metallurgical (coking) coal used as a feedstock for steelmaking (Noble & Luttrell, 2015b).

2.5.1 Coal Blending Techniques

Blending of coals of different types at pulverised coal-fired power stations is becoming increasingly common as electric utilities attempt to save costs, meet SO₂ emission regulations and improve the combustion behaviour of their coals. In countries like Australia, Germany, Poland, South Africa, and the UK, there are growing opportunities for the internal trading and blending of coals. However, in country such as the Czech Republic, Greece, and Turkey, where the majority of coals are of low rank and grade, blending opportunities are limited, as these coals are typically not transported long distances or traded. Furthermore, in countries with underdeveloped infrastructure, the potential for trading and blending is also constrained (L L Sloss, 2014).

Coals are blended for a number of different reasons, including:

1. Taking advantage of changing coal prices on the international coal market. The increased availability of different coal grades could make it profitable to purchase a relatively high percentage on the spot market;
2. Blending is shifting the high-sulfur coals to low-sulfur coals and help utilities meet tightening SO₂ emission limits;
3. Providing a fuel that possesses better combustion properties and behaviour than the component coals by themselves, and minimizing the deleterious properties of the individual coals; controlling the mineral content of coal, either independently or together with physical coal cleaning;

4. Blending a less expensive coal with a higher cost coal results in a cheaper coal, giving the producer a better chance to make a sales profit;
5. Increase a coal's marketability. In some cases, coals are so poor in quality that only when blended with a high-quality coal can they be marketed; supply a coal product which cannot be delivered with a single coal;
6. Replace current sources as existing contracts expire; and reduce day-to-day seam variations in individual coals (Xi-jin et al., 2009).

At coal mining sites, when coals from various seams or pits are mixed together: Occasionally coals of a lower or higher grade are purchased for blending with a mine's coal to meet a particular coal specification at a lower cost, at coal preparation plants, where coals from different seams and/or mines are cleaned. Raw and washed coals can be mixed together before cleaning to increase the yield. The cleaned products can be blended to meet the required coal specification (Noroña & Laureta, 2024).

The blending of imported and domestic coal is becoming increasingly important, especially in response to changing coal markets. Previously, coal blending in power stations was primarily used to reduce generation costs and increase the use of locally sourced coal. Lower-quality coals, which have high ash content, are mixed with higher-quality imported coal to avoid compromising the boiler's thermal performance, thereby cutting down on generation expenses. As the availability of domestic coal declines or becomes more costly to mine, blending with imported coal has become essential. However, ensuring that the blend maintains consistent plant output without damaging the boiler can be challenging. Additionally, coal blending is sometimes used as a pollution control strategy, such as combining inexpensive high-sulfur coal with more expensive low-sulfur coal to meet sulfur emission standards. It is also possible to blend different types of coal to enhance mercury reduction (L L Sloss, 2014).

2.5.2 Coal Washing Processes

Modern coal processing plants can be categorized into four different circuits based on the size of the coal particles being treated: (a) the coarse coal processing circuit, which treats particles larger than 10 mm; (b) the small coal circuit, which washes particles in the size range of 1-10 mm; (c) the fine coal circuit, which cleans particles in the size range of 0.15–1 mm; and (d) the ultra-fine coal processing circuit, which treats particles smaller than 0.15 mm (Jyothi & Parhi, 2021).

The equipment typically used in these coal processing circuits can be broadly grouped into three categories based on their ability to handle different particle size fractions: sizing devices, washing/cleaning devices, and dewatering devices. Sizing devices include grizzly feeders, vibrating screens, sieve bends, and classifying cyclones. The equipment used for washing coal includes drum separators, jigs, dense media cyclones, spiral concentrators, teeter-bed separators, water-only cyclones, shaking tables, and flotation cells/columns. Solid-liquid separation in coal processing circuits is achieved through various dewatering equipment, such as high-frequency screens, centrifuges, thickeners, and filters (Jyothi & Parhi, 2021).

2.5.3 Evaluating Process Units

Evaluating process units within coal washing plants is essential for ensuring operational efficiency and effectiveness. Process units, including feeders, crushers, screens, and washing machines, must be optimized to achieve the desired coal quality while minimizing energy consumption and operational costs. Performance metrics, such as recovery rate, yield, and the quality of the washed coal, are crucial for assessing the efficiency of these units.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The ET-coal washing plants in the Dawuro Zone, Southwest Ethiopia, are struggling to achieve the expected recovery rates, production quantities, and product quality, which directly impact their profitability. Profitability depends on factors such as the amount of recoverable usable coal, the quality of the produced products, production costs, and market demand. The plants face significant challenges, including low coal quality and inadequate quantities. They also lack a flotation circuit, preventing the recovery of fine coal, and do not have blending technology. Additionally, the plants are not effectively addressing their environmental impact.



Figure 4: ET-coal washing plant in Dawuro, southwestern Ethiopia.

3.2 Project Design

Blending process improving coal mineral recovery rates compared to non-blended coal processing by measuring the moisture content, ash content, calorific value, sulfur content and fixed carbon of the processed coal and compare it to expected laboratory values.

A mixed-methods approach is adopted, integrating both quantitative and qualitative methods to provide a comprehensive analysis of feed quality, blending strategies, and process unit efficiency in coal washing plants.

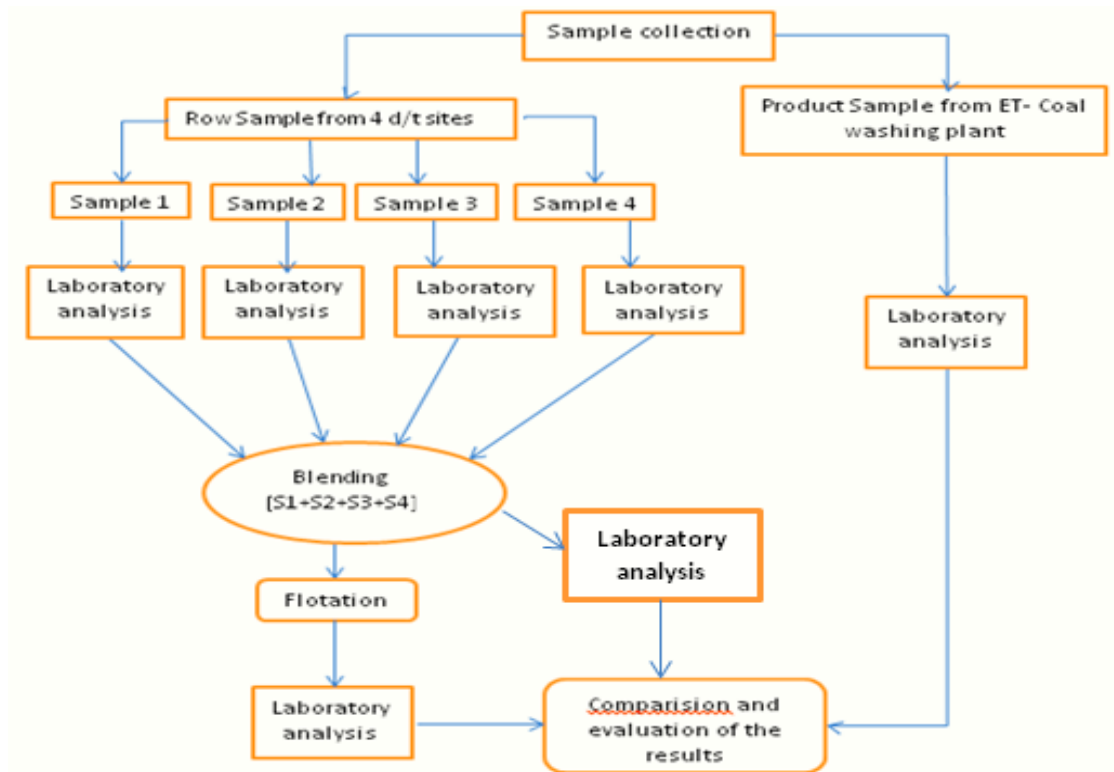


Figure 5: Project design framework of the study

3.3 Data Collection

In this project work data collection occurs both in the office and in the field, each serving specific purposes and contributing to overall operational efficiency.

3.3.1 Field Data Collection

Field data collection involves gathering real-time information directly from the study area (environment). This data helps to monitor operations, assess material quality, and ensure that processes align with operational goals.

3.3.2 Sampling

3.3.2.1 Row coal sampling

4kg of representative row coal samples were gathered from four different seams in the mining site to assess their physical and chemical properties. The samples collected from four (xy)-coordinate points, they are sample 1: (0297957, 0787240), sample 2: (0304054, 0788534), sample 3: (0304054, 0788570) and sample 4: (7°13'33", 36°49'39"). The samples underwent laboratory testing to measure key parameters such as ash content, calorific value, sulfur content, moisture content, volatile matter, and fixed carbon. These parameters are essential for evaluating the coal's suitability for various industrial uses.

3.3.2.2 Product sampling from Coal Washing Plant

1kg of cleaned coal samples was taken from operational coal washing plants to assess the effectiveness of the washing process indicate (Figure 6).

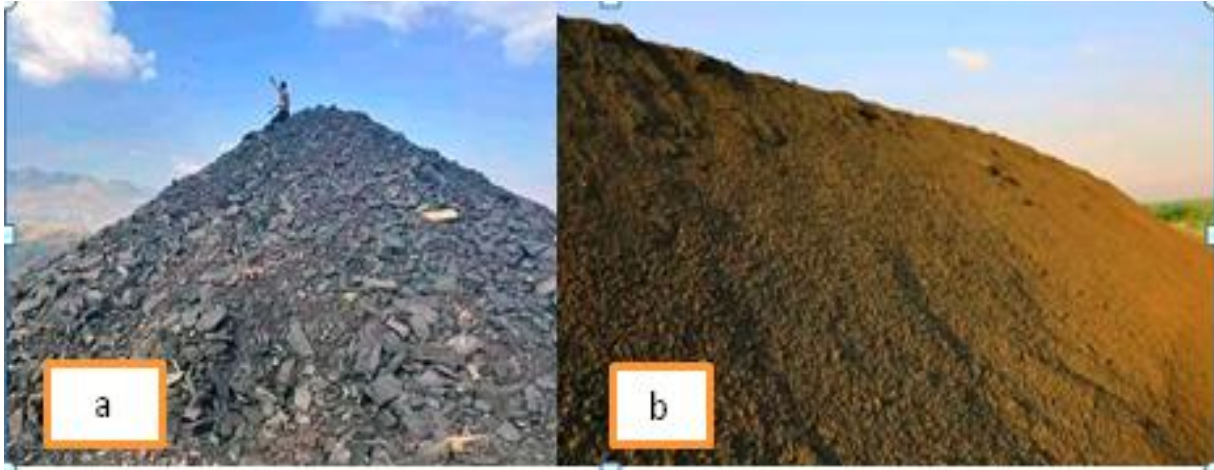


Figure 6: difference between row and washed coal samples
a) Coal before cleaned and b) Coal after cleaned

3.3.3 Laboratory Analysis

I. Sample Collection includes:

- ❖ Four raw coal samples of coal collected from various points in the processing line to ensure representative sampling.
- ❖ One product coal sample is collected from the final output of the coal processing plant.



Figure 7: Coal Samples, a) before Washed and b) after Washed

II. Preparation of Samples:

- Dry the samples at a controlled temperature to remove moisture.
- Crush and grind the samples to a uniform particle size to ensure consistency in analysis were indicated (figure 8).



Figure 8: Preparation of samples shows 1kg coal for crushing, b) sample after crushing, c) sample after grinding, d) sample during screening, e) checking balance/instrument/ before adding the sample it must be 0.0g and f) 100.0g of prepared sample for further analysis.

III. Labelling

Clearly label each sample with unique identifiers, including the collected location, date, time, sample type and size distributions show (Table 1 and Figure 9).

Sieve Analysis

The provided data contains the weight of coal passing through five aperture sizes (mesh sizes) after screening. This indicates the distribution of coal particles across various sizes. The data includes five different samples and the weight of coal that passes through each aperture size show (Table 1).

Table 1: Sample size distribution

Aperture size, (micron)		Sample 1	Sample 2	Sample 3	Sample 4	Washed Coal by ET-Coal washing Plant
Passing(-)	Passing (+)	Weight,(g)	Weight,(g)	Weight,(g)	Weight,(g)	
	500	452.6	451.0	439.6	443.3	371.7
500	250	199.3	217.2	217.3	195.9	191.6
250	150	126.0	117.5	108.0	109.9	107.5
150	125	24.1	26.4	30.5	35.9	35.8
125	100	47.1	40.3	32.6	33.6	27.6
100	0	137.2	130.6	157.5	171.7	229.2



Figure 9: Coal samples, clearly identified by date, time, sample type (feed or product), and collected location.

3.4 Coal Blending Before Washing

Coal blending before washing is the process of combining various coal grades to create a consistent feed that can be efficiently processed in coal washing plants. This is done to optimize the washing process, ensuring that the final product meets the desired quality specifications. The methodology for blending involves:

Selection of coal

- **Source Identification:** The selection of coal types for the washing process starts with identifying the source of the coal. This involves determining the coal's origin, grade, ash content, sulfur content, moisture level, and calorific value. Each of these characteristics plays a crucial role in selecting the right coal for the specific processing requirements. For instance, coals with higher sulfur content may need to be blended with lower-sulfur coals to meet environmental standards, while coals with varying moisture levels may require specific washing techniques to reduce excess water content.
- **Proportional Mixing:** This is done to optimize the washing process and achieve the desired output quality, such as controlling the ash content, sulfur levels, and calorific value. The blend ratio ensures that the final product meets market specifications and operational performance standards. For example, a blend may be designed to lower the overall ash content in the product or to achieve a target calorific value to meet energy requirements. Achieving the right proportions of each coal type allows for a more controlled washing process and better overall quality in the final coal product.

Blending Process

- **Weighing:** Accurately weighing each type of coal is an essential step before blending. By precisely measuring the weight of each coal type, the correct proportions are ensured, which

is critical for achieving the desired quality. Weighing prevents any discrepancies in the blend ratio and helps maintain consistency in the coal products produced. Inaccurate weighing could result in variations in the final product, such as higher ash content or lower calorific value than intended. Using accurate weighing equipment ensures that the coal mix adheres to the planned ratios for optimal processing results. A diagram or illustration (e.g., Fig. 6a) can be used to show the equipment setup and weighing process.

- **Blending Equipment:** After weighing, the next step is to mix the coals using a blending system. In mechanical blending systems, various devices such as conveyors, mixers, and rotary drums are used to ensure that the coal types are thoroughly mixed to achieve uniformity in the final blend. These systems often incorporate automated processes that allow for consistent blending over a larger scale and reduce human error. On the other hand, manual blending involves physically mixing the coal types by hand or with simpler tools, which can be suitable for smaller-scale operations. Regardless of the method used, it is important to ensure that the coal is evenly mixed to avoid any inconsistencies in the final coal product, ensuring it meets the desired specifications, such as ash content, sulfur levels, and calorific value.

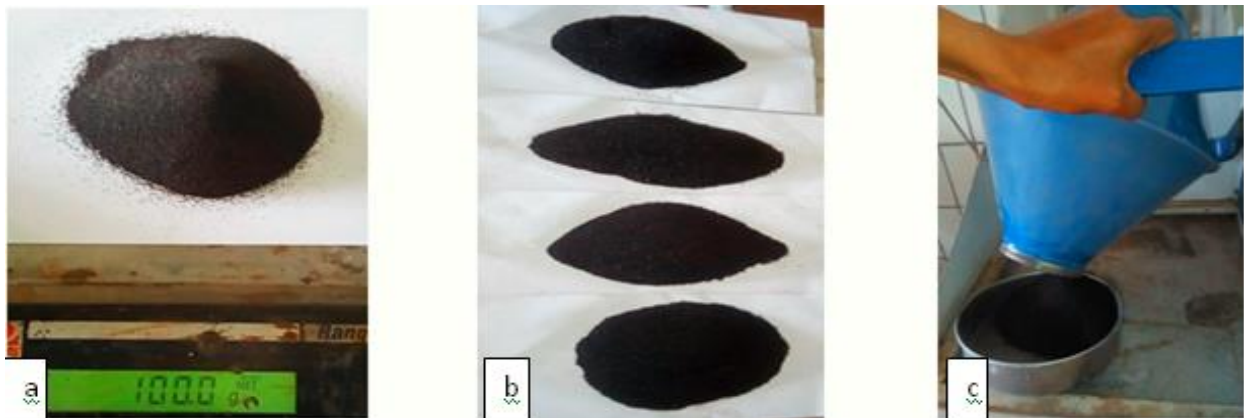


Figure 10: Coal Blending Techniques show: a) Measuring the Weight of Samples b) Prepare four different samples for mixing, c) Mixing four samples by using mixer.

Homogenization and Storage of coal samples during preparation

- I. After blending, the coal should be stored in a controlled environment to avoid segregation or moisture loss.
- II. Moisture Control, Store blended coal in a way that prevents excessive moisture absorption, as this could affect its quality and washing efficiency.

3.5 Flotation

Flotation is an important method used in coal processing to separate valuable coal from impurities to improve the quality of the coal and meet the required specifications for use in industries. Fine coal, typically coal particles smaller than 0.5 mm, is difficult to separate using traditional gravity methods, but flotation can efficiently remove impurities from these fine particles. According to this data and common flotation practices, the (-150+125) micron and (-125+100) micron size ranges are likely the most suitable for flotation.

The distribution of the sample mass in these size ranges is still considerable, indicating that these sizes strike a good balance for achieving optimal flotation efficiency (Shown Table 1).



Figure 11: Coal flotation procedure

Quality Control: Conduct preliminary checks to ensure that all samples are free from contamination and properly labelled.

Chemical Analysis

Proximate analysis of coal is a technique used to assess the fundamental composition of a coal sample, which includes its moisture, volatile matter, ash, and fixed carbon content. This analysis offers important insights into the coal's combustion characteristics and helps predict its performance during industrial burning processes.

The Geological Institute of Ethiopia carries out proximate analysis, sulfur content and calorific value on coal samples and I have also conducted tests on ash content and moisture content as well. The results of these analysis are presented in the appendix.



Figure 12: Measuring ash and moisture content.

3.6 Process Units in ET-Coal Washing Plant

The coal preparation plant's processing units are mainly intended to refine coal to ensure it satisfies the quality requirements for combustion or various industrial applications. This process is depicted in the (Figure 13) below.

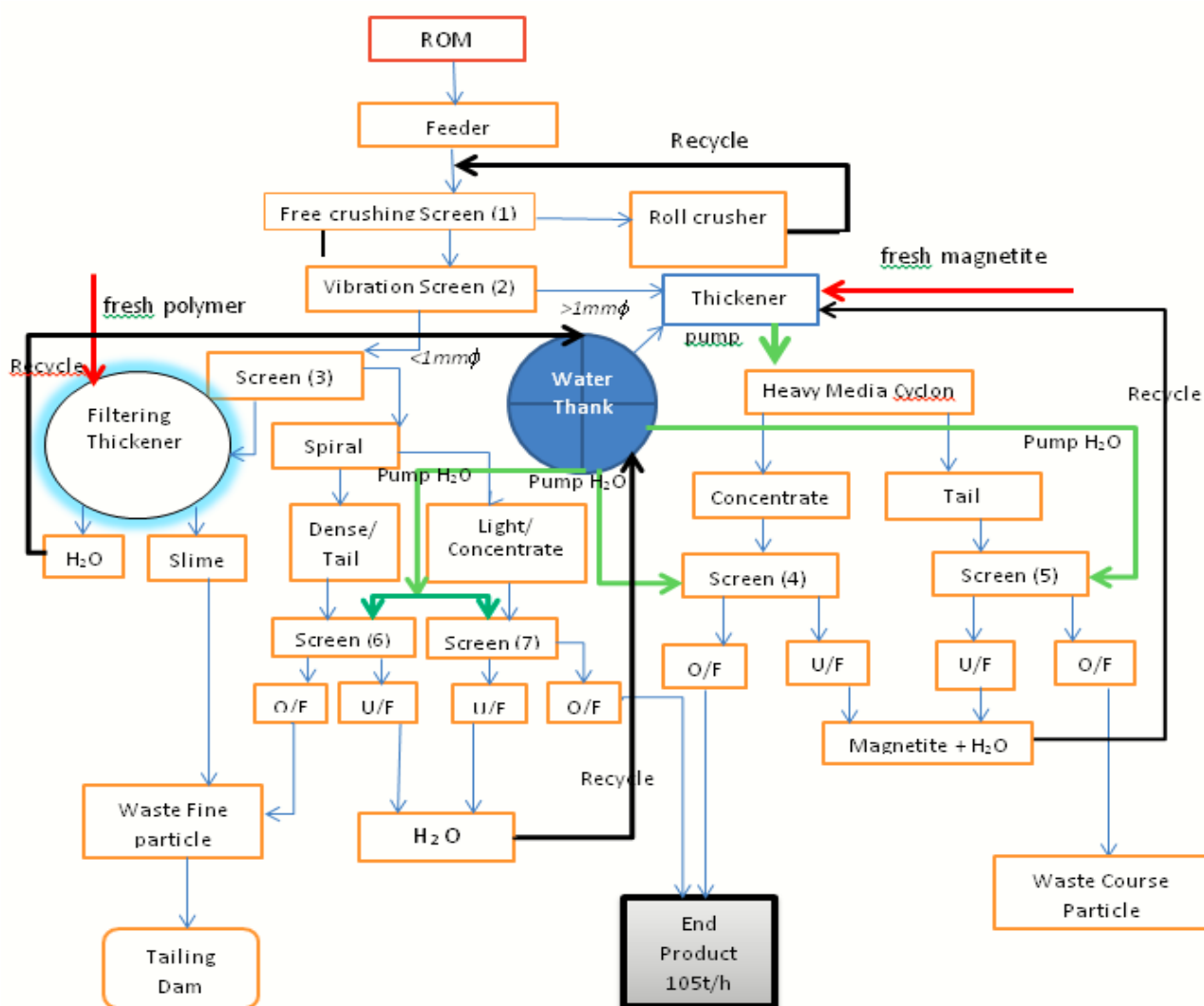


Figure 13: ET- Coal processing /washing/ plant flowsheet.

3.6.1 Material Balance Calculations

By using the equation: Input = Output + Loses-----Eq (1)

Output = Product + Loses + Waste, Therefore:

Input = Product + Losses + Waste-----Eq (2)

Then, the overall material balance of the ET- Coal processing plant is 150 t/h = 105 t/h (Product) + 45 t/h (Loss & Waste).

3.6.2 Performance Testing

To analyze the efficiency of each coal washing unit in a coal processing plant, we need to focus on **recovery rates**, which refer to the amount of clean coal recovered from the raw feed material after processing. A high recovery rate indicates an efficient process where most of the valuable coal is extracted, while minimizing the loss of clean coal or increasing the separation of waste materials (impurities).

Table 2: Data of cleaned and row coal after Combustion

Sample Types	Mass of Concentrate (g)	Mass of Tailing (g)	Mass of available coal (g)	Available coal (%)	Ash content (%)
Cleaned coal	70	30	58.877	84.11	15.89
Row Coal	100	-	76.4	76.4	23.6

➤ **Washing Efficiency (WE):** Measures the effectiveness of the separation between clean coal and impurities (waste).

$$\text{Washing Efficiency(\%)} = \frac{\text{Amount of Clean Coal Produced}}{\text{Amount of Feed Coal}} \times 100 \quad \text{-----Eq(3)}$$

$$\text{Therefore: WE} = \frac{70}{100} * 100$$

$$\underline{\underline{\text{WE} = 70\%}}$$

The efficiency of coal washing units is typically evaluated based on their recovery rates, which measure how effectively they can extract clean coal from raw feed. The recovery rates of different units vary based on the type of equipment, feed quality, particle size, and operational conditions. The key to maximizing the efficiency of coal washing units lies in optimizing operating parameters and choosing the appropriate washing method for the specific feed characteristics.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Data Presentation

The process begins with blending different coal feeds sourced from various coal seams or stock-piles. These feeds can vary in terms of particle size, ash content, sulfur levels, and other impurities. The objective of this blending is to produce a homogeneous feed that achieves a consistent quality before it undergoes further processing like flotation. This step ensures that the coal is representative of the desired grade and will perform well in the subsequent separation processes.

4.1.1 Feed Coal Sample Results

Four representative coal samples were collected from different seams within the mining region to evaluate their physical and chemical properties. The samples underwent laboratory analysis to determine key parameters such as **ash content, calorific value, sulfur content, moisture content, volatile matter and fixed carbon**, which are critical for assessing their suitability for various industrial applications (Shown table 3).

Table 3: Coal Laboratory results of the row samples

Sample Name	Sample 1	Sample 2	Sample 3	Sample 4
Ash Content (%)	13.28	12.97	35.43	12.90
Calorific Value (kcal/kg)	5089.39	6177	5615	4804.07
Sulfur Content (%)	0.87	0.6	2.13	0.36
Moisture Content (%)	18.96	13.30	5.44	21.54
Volatile Matter (%)	30.14	33.77	23.20	31.41
Fixed Carbon (%)	37.62	39.96	35.93	34.14

This table offers a comprehensive comparison of the coal properties across four distinct samples, providing valuable insights into their combustion efficiency and environmental effects.

Optimal Sample for Energy Efficiency, Sample 2 stands out with the highest calorific value (6177 kcal/kg), low sulfur content (0.6%), and a relatively high volatile matter percentage (33.77%), are making it a strong contender for efficient energy production and effective combustion. Sample 4 is the top choice for reducing environmental pollution, thanks to its very low sulfur content (0.36%) and relatively low ash content (12.90%), which help minimize sulfur emissions during combustion. Sample 1 strikes a good balance, offering a decent calorific value (5089.39 kcal/kg), low ash content (13.28%), and moderate sulfur content (0.87%), making it a reliable choice for both energy production and environmental performance.

The most suitable coal sample depends on the specific needs of the application whether it's prioritizing energy efficiency, minimizing environmental impact, or optimizing combustion characteristics. Sample 2 is best for high energy output, while Sample 4 is the optimal choice for reducing sulfur emissions.

4.1.2 Blended coal Sample results before flotation

Four different coal samples that have been mixed or blended, and then tested after blending, then the organized laboratory results are given in the (Table 4) below. This approach provides a clear comparison of each sample's characteristics before and after blending, helping to evaluate the quality of the blended coal and make informed decisions about its use in industrial applications. The Table 4 shows comparison of the individual properties of each sample before blending and the combined results after blending, allowing for a clear understanding of how the mixture performs compared to individual samples.

Table 4: Laboratory Result of Coal Samples before and after blending

Sample Name	Sample 1	Sample 2	Sample 3	Sample 4	Row Mixed Coal
Ash Content (%)	13.28	12.97	35.43	12.90	23.60
Calorific Value (kcal/kg)	5089.39	6177	5615	4804.07	5301.62
Sulfur Content (%)	0.87	0.6	2.13	0.36	1.96
Moisture Content (%)	18.96	13.30	5.44	21.54	6.55
Volatile Matter (%)	30.14	33.77	23.20	31.41	32.39
Fixed Carbon (%)	37.62	39.96	35.93	34.14	37.46

(Table 4) shown demonstrates that blending Sample 2 (which has a high calorific value and low sulfur content) with Sample 4 (low sulfur and moisture content) and Sample 3 (low moisture but high sulfur content) results in a more balanced coal mixture, leading to enhanced overall performance.

4.1.3 Blended Coal Sample Results after Flotation

The data given below (Table 5) shows the Laboratory analysis of three different coal types: **row mixed coal**, **cleaned coal by ET-Coal washing plant**, and **mixed coal after flotation**. A comparison of the laboratory results for key parameters, along with explanations for each, is:-

- ❖ **Ash content** decreases significantly after the washing and flotation processes. The washing and flotation processes effectively reduce the amount of impurities in the coal.
- ❖ **Calorific value** increases after flotation treatment, suggesting that the flotation process is more effective in enriching the coal's energy content. This would make the coal after flotation more efficient for energy production compared to the mixed and cleaned coals.

- ❖ **Sulfur content** decreases slightly with both the cleaning and flotation processes. Sulfur is undesirable in coal as it leads to air pollution (e.g., sulfur dioxide emissions). However, the reduction is not drastic, and sulfur content still remains relatively high, which could be a concern for environmental impact.
- ❖ **Moisture content** - there is a notable increase in moisture content after the coal is washed, but a significant reduction after flotation. High moisture content in coal reduces its calorific value and handling efficiency. The flotation process not only reduces ash but also moisture, making it more suitable for energy generation.
- ❖ **Volatile matter** increases after flotation, which can improve the coal's combustibility and its ability to produce gases for energy generation. However, too much volatile matter can also lead to uncontrolled combustion or reduce the thermal efficiency of the coal.
- ❖ **Fixed carbon** increases slightly after both ET-coal washing plant and after flotation, indicating that the processes concentrate carbon in the coal, making it more efficient as a fuel.

In generally the flotation process shows the most significant improvements in terms of calorific value, ash reduction, and moisture content, although the sulfur content and volatile matter also see changes. While flotation improves the coal's overall quality and makes it more suitable for energy production, the high sulfur content and volatile matter might still pose environmental and combustion-related challenges.

Table 5: demonstrate the laboratory result of cleaned by ET- Washing Plant, row mixed samples and row mixed after flotation

Sample Name	Row Mixed Coal	Cleaned Coal by ET-Coal Washing Plant	Mixed Coal after Flotation
Ash Content (%)	23.60	15.89	14.97
Calorific Value (kcal/kg)	5301.62	5311.59	6540.27
Sulfur Content (%)	1.96	1.50	1.4
Moisture Content (%)	6.55	14.72	0.96
Volatile Matter (%)	32.39	31.01	43.96
Fixed Carbon (%)	37.46	38.38	40.11

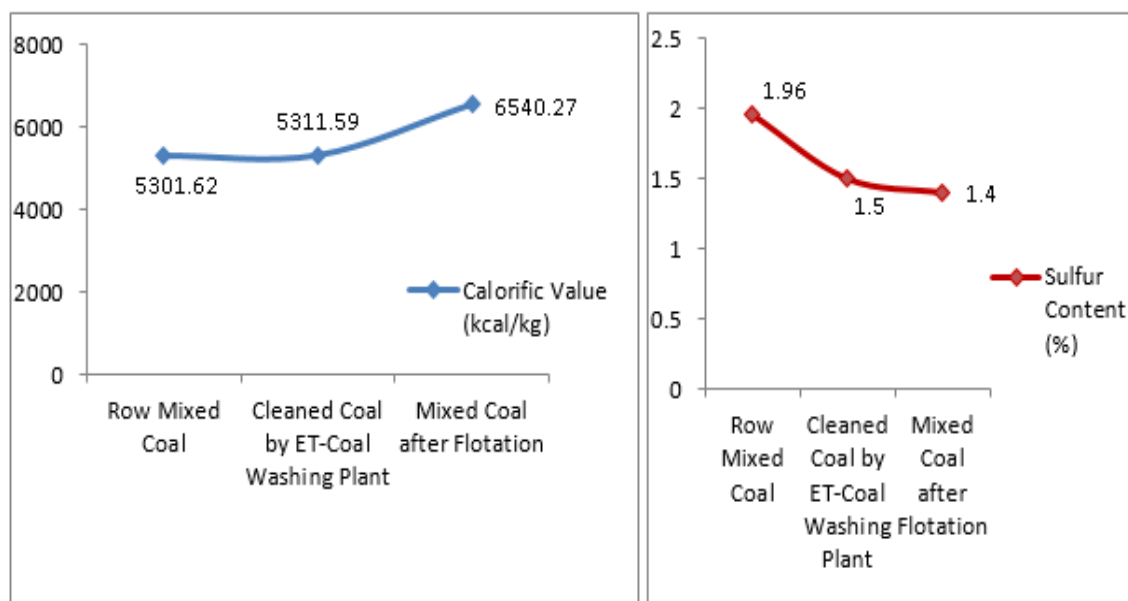


Figure 14: Calorific Value and Sulphur Content of cleaned coal by ET- Washing Plant, Row Mixed Samples and Row mixed sample after flotation

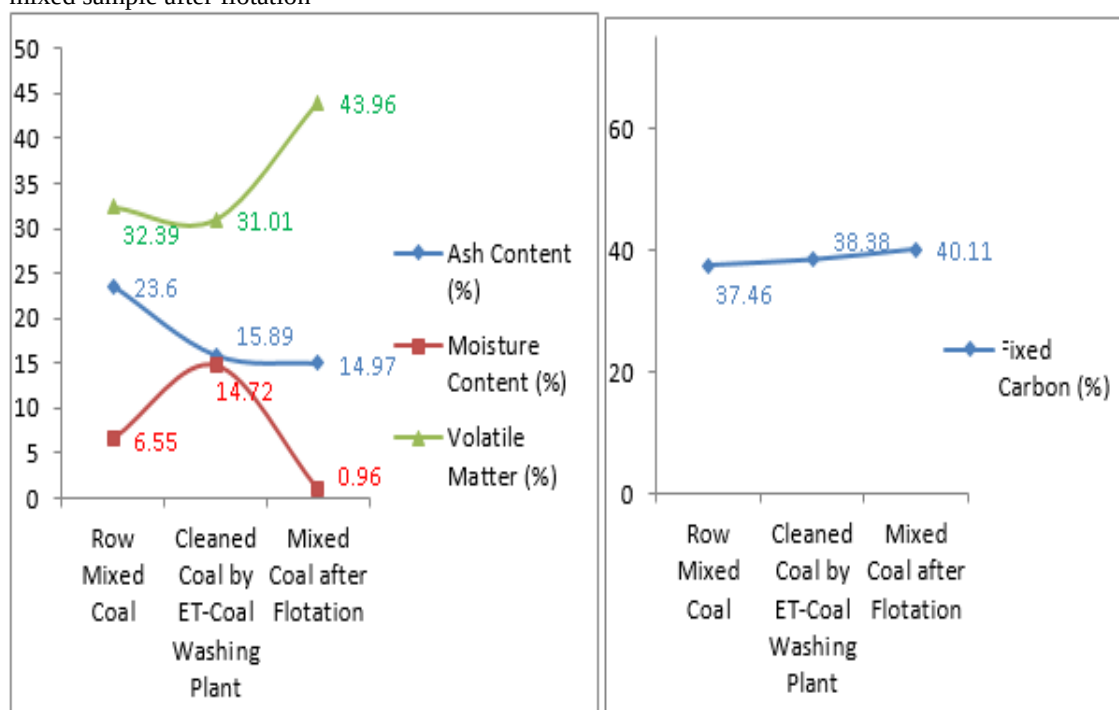


Figure 15: proximate value of cleaned coal by ET- Washing Plant, Row Mixed Samples and Row mixed after flotation.

Table 5 presents a comparison of the coal properties for three coal types: Row Mixed Coal, Cleaned Coal from the ET-Coal Washing Plant, and Mixed Coal after Flotation. The data provides important insights into how the washing and flotation processes impact the characteristics of the coal.

For Maximum Energy Output: Mixed Coal after Flotation is the best option, with the highest calorific value (6540.27kcal/kg), low moisture content (0.96%), and relatively low sulfur content (1.4%). Its high volatile matter (43.96%) and fixed carbon (40.11%) ensure fast yet stable combustion. This coal would be ideal for applications where energy efficiency is the highest priority.

For Lower Environmental Impact: Cleaned Coal by ET-Coal Washing Plant is the preferred choice, offering lower sulfur content (1.50%) than the row mixed coal, along with reduced ash content (15.89%). The cleaning process reduces environmental pollutants, making it suitable for more eco-conscious operations. Although its calorific value (5311.59 kcal/kg) is slightly lower than that of the flotation-treated coal, it remains a good option for environmentally responsible energy production.

For Balancing Cost and Efficiency: Row Mixed Coal could be used in a blend when cost is a more significant factor than efficiency or environmental impact. Its higher ash content (23.60%) and sulfur content (1.96%) make it less desirable alone, but it can be used in combination with cleaner coals (like cleaned coal by flotation) to achieve a balance between cost and performance.

Recovery and Grade of the Floated Row Mixed coal and Washed by ET-coal Washing plant

Table 6: data of concentrate and tailing, before and after combustion available coal and ash content of 3-samples

Sample Types	Mass of Concentrate(g)	Mass of Tailing(g)	Mass of available coal (g)	Available coal (%)	Ash content (%)
Cleaned coal by ET - Washing plant	70	30	58.877	84.11	15.89
Mixed coal after Flotation	81	19	68.8743	85.03	14.97
Row Mixed coal	100	-	76.4	76.4	23.6

To calculate the recovery and grade of the flotation process of the mixed coal and Washing process of ET -coal Washing plant by using the following formula:

$$\text{Recovery (\%)} = \frac{\text{weight of concentrate} \times \text{assay of concentrate}}{\text{mass of feed} \times \text{assay of feed}} \times 100 \text{ -----Eq (4)}$$

$$\text{Grade \%} = \frac{\text{weight of pure coal in concentrate}}{\text{weight of concentrate}} \times 100 \text{ -----Eq (5)}$$

1. Washing process of ET -coal Washing plant

➤ By using equation 4: $\text{Recovery \%} = \frac{70 \times 84.11}{100 \times 76.4} \times 100$

Recovery = **77.06%**

➤ By using equation 5: $\text{Grade (\%)} = \frac{58.877}{70} \times 100$

Grade = **84.11%**

2. flotation process of the mixed coal:

By using equation 4: $\text{Recovery \%} = \frac{81 \times 85.03}{100 \times 76.4} \times 100$

Recovery = **90.15%**

By using equation 5: $\text{Grade (\%)} = \frac{68.8743}{81} \times 100$

Grade = **85.03 %**

Table 7: Recovery and Grade data of mixed coal after Flotation and Cleaned coal by ET -Washing plant

Sample Types	Weight of Concentrate(g)	Weight of available coal from combustion (g)	Recovery (%)	Grade (%)
Cleaned coal by ET -Washing plant	70	58.877	77.06	84.11
Mixed coal after Flotation	81	68.8743	90.15	85.03
Row coal	100(No have any process)	76.4	-	-

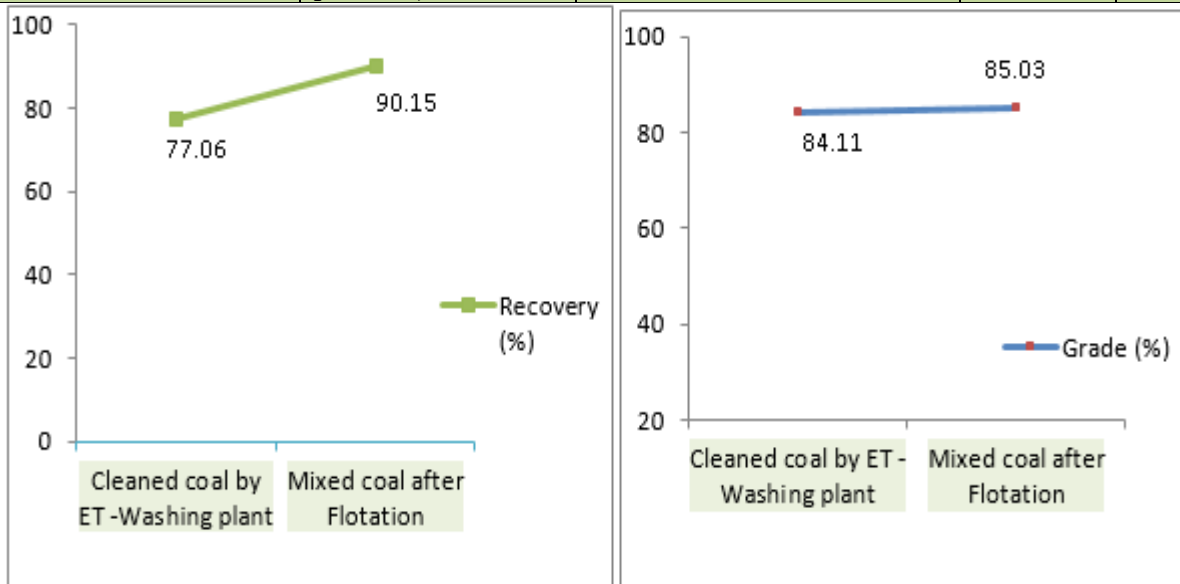


Figure 16: Figure the graph which shows Recovery and Grade result of mixed coal after Flotation and Cleaned coal by ET -Washing plant.

The recovery percentage of Cleaned Coal by ET-Washing Plant: is 77.06%, which means that around 77% of the original coal was successfully processed and retained as usable coal after washing. This is a moderate recovery rate, indicating that a fair amount of the coal is still usable

after the washing process, but some loss has occurred during cleaning and the recovery rate of mixed coal after flotation is 90.15% is quite high, indicating that the flotation process has been effective in retaining most of the coal, with very little loss during the process.

The grade of Cleaned Coal by ET-Washing Plant is 84.11% indicates that the coal product obtained after washing is of relatively high quality, likely with lower ash content and other impurities removed, making it better for combustion and energy production and the grade of mixed coal after flotation is 85.03% is also quite good, showing that the flotation process results in a relatively high-quality coal product, likely with a good calorific value and lower impurities shown (Table 7) & (Figure 16).

Comparison of Economic Advantages of Coal Based on Laboratory Results and accepted standard Ranges

Coal forms in four stages: peat, lignite, bituminous, and anthracite. As coal rank increases, it becomes denser, with less moisture and gases, and a higher heat value compared to lower-rank coal (Chou, 2012). Coals typically have high ash content (ranging from >30%), high moisture content (>10%), low sulfur content (<1%) and low calorific values (between 2500 and 5000 kcal/kg) (shown Table 8).

Table 8: Evaluation the range of data depending on laboratory analysis (Meshram et al., 2015)

Property/ Test	Best Range	Medium Range	Lower/Harmful Range
Ash Content (%)	<10% (low ash, clean combustion)	10-20% (moderate ash, suitable for some industrial use)	>20% (high ash, reduces efficiency and causes disposal issues)
Moisture Content (%)	<6% (low moisture, optimal for combustion)	6-10% (moderate moisture, acceptable for power generation)	>10% (high moisture, decreases calorific value and efficiency)
Volatile Matter (%)	25-35% (ideal for combustion, good burn rate)	35-45% (moderate volatile content, some efficiency loss)	>45% (high volatile matter, can cause excessive smoke and loss of energy)
Calorific Value (kcal/kg)	>7,500 kcal/kg (high calorific value, ideal for energy generation)	5,500-7,500 kcal/kg (moderate calorific value, suitable for industrial use)	<5,000 kcal/kg (low calorific value, poor for power generation)
Sulfur Content (%)	<1% (low sulfur, environmentally friendly)	1-2% (moderate sulfur, may require emissions control)	>2% (high sulfur, harmful to environment and requires control)
Fixed Carbon (%)	>45% (high fixed carbon, efficient combustion)	35-45% (moderate fixed carbon, balanced combustion)	<35% (low fixed carbon, poor combustion efficiency)

By flotation-treated coal provides the most balanced improvement in both efficiency and environmental considerations, making it the most economically advantageous option for energy generation among the three coal types (shown table 8).

4.2 Discussions and Interpretations

The process starts with blending different coal samples, which are sourced from various coal seams. These raw coal samples can vary significantly in terms of particle size, ash content, sulfur content, and other impurities. The primary goal of blending these coals is to produce a more uniform feed that meets specific quality standards before undergoing further processes, such as flotation. This step is crucial to ensure that the coal maintains consistent quality throughout the subsequent separation processes, which ultimately enhances its suitability for industrial applications.

4.2.1 Environmental Considerations

Coal washing plants are crucial in preparing coal for various industrial uses by removing impurities such as ash, sulfur, and other contaminants. However, coal washing processes can present significant environmental challenges, especially when the coal has high sulfur content and lacks flotation circuits, which are commonly used to separate sulfur-rich particles from the coal.

Air Pollution (Sulfur Dioxide Emissions):

Coal with high sulfur content releases sulfur dioxide (SO₂) when burned. This contributes to air pollution and can lead to acid rain, which harms soil and aquatic ecosystems. Coal washing processes that don't adequately reduce sulfur content allow these pollutants to enter the atmosphere at higher levels.

Water Contamination:

Coal washing involves using water to separate impurities. This water, known as coal slurry, can be contaminated with toxic substances such as heavy metals, fine coal particles, and sulfur compounds.

Solid Waste (Tailings):

The washing process generates tailings, which are residues left after impurities are removed. If the coal washing plant fails to properly handle and dispose of these tailings, they can accumulate and cause environmental harm. Tailings from high-sulfur coal can be particularly dangerous as they may contain sulfur compounds that can leach into the soil and waterways, potentially leading to acid mine drainage.

Soil Contamination:

If the tailings or slurry are improperly managed or disposed of on-site, sulfur compounds can leach into the surrounding soil. This can result in soil acidification, making it less fertile and unsuitable for agricultural or natural vegetation.

Greenhouse Gas Emissions:

Though not as directly associated with coal washing itself, the overall lifecycle of coal, including mining, washing, and burning, contributes significantly to greenhouse gas emissions. The energy-intensive nature of washing plants adds to the environmental footprint of coal use.

4.2.2 Mitigation Methods of the Environmental Issues

Flotation Circuit Implementation:

Introducing flotation circuits can significantly improve sulfur removal. Flotation uses chemicals and air bubbles to separate sulfur and ash from the coal, thereby lowering the sulfur content in the final product. This helps in reducing sulfur dioxide emissions when the coal is burned, improving air quality and mitigating acid rain formation.

Desulfurization:

Chemical desulfurization techniques, such as the use of solvents or oxidizing agents, can be employed to chemically reduce sulfur levels in coal before it is burned. This treatment can significantly lower sulfur emissions and minimize environmental impact. In some cases, sulfur-rich coal can be blended with lower-sulfur coal to reduce the overall sulfur content.

Water Treatment and Recycling:

Proper treatment of coal slurry and wastewater is crucial to minimize the environmental impact. Installing effective water treatment systems such as sedimentation ponds, filtration units, or chemical treatment can help remove contaminants from wastewater before it is discharged. Recycling and reusing water within the plant can reduce the overall demand for fresh water, reducing the risk of contamination of nearby water sources.

Tailings Management:

Proper disposal and storage of coal tailings are essential. Tailings can be stored in specially designed tailing ponds or landfills that are lined to prevent leakage of contaminants into the surrounding environment. Technologies like dry stacking, where tailings are dewatered and stored in a dry form, can reduce the risk of contamination and land degradation.

Sustainable Coal Processing Technologies:

Newer technologies like supercritical fluidized bed combustion or clean coal technologies can be applied to minimize the sulfur content in coal and reduce the emissions produced during combustion.

Bioleaching and other biologically based sulfur removal methods can be used as an alternative to traditional chemical methods to further reduce sulfur levels.

Environmental Monitoring and Compliance:

Continuous monitoring of emissions, wastewater discharge, and tailing ponds is essential to ensure that environmental regulations are being met and that harmful contaminants are not released into the environment.

Strict adherence to regulatory standards and best practices for environmental management can mitigate many of the potential environmental impacts of coal washing plants.

4.2.3 Economic and Operational Efficiency

Evaluating the process units in the ET-Coal Washing Plant (without a flotation circuit and using spiral separation and heavy media separation) can be done from several perspectives, focusing on economic, engineering, and other relevant aspects:

1. Economic aspects:

- **Capital Costs:** The use of spiral separators and heavy media separation typically involves lower capital investment compared to flotation circuits, as these processes are less complex and require fewer infrastructures. However, the absence of flotation may limit the plant's ability to process lower-grade coal efficiently.
- **Operating Costs:** Heavy media separation requires ongoing maintenance and media recovery, which can be costly. Spiral separators, while cheaper to operate, have lower separation efficiency, higher consumption of water and energy.
- **Revenue:** Without flotation, the plant may not be able to recover fine coal (which flotation is typically designed for), potentially reducing overall product yield and revenue, particularly if the coal has a significant fine fraction that would otherwise be recoverable.

2. Engineering aspect:

- **Efficiency:** Spiral separation and heavy media separation are effective for coarse coal fractions but have limitations in recovering fine coal or coal with complex impurities. This may result in lower overall recovery rates compared to a plant with a flotation circuit.

- **Flexibility:** The plant might struggle to handle varying coal qualities effectively. A flotation circuit could improve processing flexibility by handling fine coal more efficiently, thus expanding feedstock flexibility.
- **Maintenance & Reliability:** Both spiral and heavy media circuits are relatively simple but require regular maintenance, particularly in media recovery and handling. Engineering improvements could enhance efficiency, but the lack of flotation may limit technological advancements in fine coal processing.

3. Environmental Aspect:

- **Water Usage:** Both spiral and heavy media separation processes require significant water usage for slurry handling. Efficient water recovery systems and waste management (such as tailings disposal) are crucial for minimizing environmental impact.
- **Waste Management:** The absence of flotation means that fine coal loss could be higher, contributing to an increase in waste tailings. This requires effective management to prevent environmental contamination, especially in terms of water quality and land reclamation.

The ET-Coal Washing Plant's use of spiral and heavy media separation offers a cost-effective, simpler approach with lower initial investment and maintenance costs but at the expense of fine coal recovery efficiency. This limits its flexibility and overall economic viability when processing diverse coal qualities. The plant's economic success will largely depend on the coal feedstock characteristics and the effectiveness of other operational optimizations.

The quality of coal required for the cement and steel/metal industries is vary depending on the specific processes and needs of each industry. Below are typical ranges of coal quality for both industries. In cement manufacturing, coal is primarily used as a fuel for the rotary kiln and the preparation of clinker. The key components for coal quality are given (table 9) below and in the steel industry, coal is primarily used as coke (which is produced by carbonizing coal), a key component in the blast furnace for producing steel.

Table 9: the common quality of ranges of coal used for the cement and steel/metal industry (Meshram et al., 2015)

Coal Parameter	Cement Industry	Steel/Metallurgy Industry
Calorific Value (CV)	4,500 to 6,000 kcal/kg	6,000 to 7,500 kcal/kg
Volatile Matter	18% to 30%	22% to 30%
Ash Content	10% to 25%	Below 10%
Sulfur Content	Below 1%	Below 1%
Moisture Content	5% to 12%	5% to 9%
Fixed Carbon	Around 40% to 50%	Not a primary concern (though generally higher in coking coal)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study on the ET-coal washing plant in the Dawuro Zone, Southwest Ethiopia, and the plant processes 150 t/h of raw coal, producing 105 t/h of clean coal and 45 t/h of waste. The plant achieves relatively high efficiency, with the final clean coal product showing a washing efficiency (WE) of 70%. This reflects a reasonable level of separation between the clean coal and waste materials, although there is room for improvement in maximizing recovery and minimizing waste. The ET-Washing Plant has a recovery rate of 77.06%, indicating moderate retention of coal after cleaning, with some loss due to impurity removal. Its grade of 84.11% reflects high-quality coal, suitable for efficient energy production. The Flotation Process shows a higher recovery rate of 90.15%, indicating minimal coal loss and greater efficiency. The grade of 85.03% suggests a similarly high-quality product, with low impurities and good calorific value. The flotation process provides better recovery and slightly higher quality, while the washing process remains effective but results in moderate recovery and a slightly lower grade. Together, both methods enhance coal recovery and quality. This study also highlights the importance of blending different coal types before washing to optimize recovery rates, coal quality, and overall profitability. Although blending is manually implemented, it has proven to improve washing efficiency by ensuring more consistent product quality. The coal-washing process, which includes screening, crushing, dense media separation, and spiral concentrators, is well-optimized to remove impurities from the coal. While there are opportunities for improvement, the recovery rates and washing efficiency indicate that the process is generally effective in producing a high-quality coal product. The flotation process proved to be the most effective for improving coal quality, significantly reducing ash content, boosting calorific value, and decreasing moisture levels. However, there are still challenges regarding sulfur and volatile matter content that require ongoing optimization to reduce environmental and combustion-related impacts.

The economic and operational analysis further confirms the advantages of flotation, particularly in terms of recovery and grade, making it the most economically viable approach. None the less, attention must be paid to environmental concerns, particularly sulfur content and the management of tailings and wastewater. By implementing mitigation strategies, such as flotation circuit installation, desulfurization, and enhanced water treatment, the environmental impact of coal processing can be minimized.

5.2 Recommendations

- ❖ **Invest in Automated Blending Technology:** The current manual blending process could be improved with automated blending equipment. This would allow for more precise control over coal feed, reducing variability and ensuring more consistent product quality.
- ❖ **Training and Capacity Building:** Ongoing training for plant operators and maintenance staff is essential to ensure efficient operations, especially in understanding coal blending and the influence of various operational parameters on the washing process.
- ❖ **Flotation Process Optimization:** The flotation process should be refined to further enhance sulfur removal and reduce volatile matter content. Integrating advanced flotation technologies would boost overall performance and make the coal more suitable for energy generation and industrial use.
- ❖ **Environmental Impact Mitigation:** To address environmental concerns, particularly sulfur emissions and water contamination, it is recommended to implement flotation circuits that effectively remove sulfur and other impurities. Additionally, adopting chemical desulfurization and improving water recycling and treatment in the washing plant will help minimize the plant's environmental footprint.
- ❖ **Tailings Management:** Tailings management should be improved to prevent environmental contamination, especially in areas with high sulfur content in coal. Sustainable disposal methods, such as dry stacking, will reduce environmental impacts.
- ❖ **Economic Feasibility of Coal Processing:** Given the economic advantages of flotation, prioritizing investment in flotation circuits is recommended. This will improve recovery rates, enhance coal quality, and increase the overall profitability of coal processing plants, especially when dealing with lower-grade coal.
- ❖ **Further Research on Coal Quality:** Additional research into the effects of different coal blends on product quality and plant efficiency would provide valuable data to refine blending ratios, ultimately improving recovery rates and product quality.

By implementing these recommendations, coal processing plants can improve coal quality, minimize environmental impacts, and enhance economic efficiency in coal production and industrial applications

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Appendix

Laboratory results: four row samples, cleaned coal by ET- Washing Plant, row coal mixed samples and row mixed after flotation.

- a. Sample 1
- b. Sample 2
- c. Sample 3(S3BD5)
- d. Sample 4
- e. Mixed coal
- f. Washed coal by ET- coal washing plant and
- g. Mixed coal after flotation.

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Document Title:-	Hydrocarbon Analysis Report	Effective date:	Nov. 2022

Customer Name :- Berhanu Aberra

Issue Date:- 30/12/2024

Sample type:- Coal Powder

Request No:- GLD/RN/685C/24

Sample Preparation:- 60 Mesh

Report No:- GLD/TR/4213/24

Date Submitted:- 12/12/2024

Number of Sample: One(01)

Elements to be determined:- (Moisture, Volatile matter, Fixed carbon and Ash), Calories & Sulfur.

Method of analysis:- Proximate Analysis, Adiabatic Caloric Metter and Gravimetric Method.

Collectors' Code	Moisture %	Volatile Matter %	Fixed carbon %	Ash %	Calorific Value cal/gm	sulfur%	Weight of Sample
Feed	18.96	30.14	37.62	13.28	5089.39	0.87	100gm

Note: - This result represent only for the sample submitted to the laboratory.

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Geological Survey of Ethiopia

Geochemical Laboratory Directorate

Hydrocarbon Laboratory analysis report format: form GD0006

File ID: 4454/17pv1

Originator: East Africa Holding S.C.

Sample type: Coal

Number of Samples: 1

Preparation required: 60 mesh

Element to be determined: (Moisture, Volatile matter, Fixed carbon and Ash), Calorie and sulfur.

Method of analysis: Proximate Analysis, Adiabatic Calorie Meter, Eschka mixture and chemical method.

customer type: pvt

Date submitted 28/03/2010 (12/06/2017)

Date completed (19/04/2010 (12/28/2017)

Field No.	Lab No.	Moisture %	Volatile Matter %	Fixed carbon %	Ash %	Calorific Value cal/gm	sulfur%
01	4454/17	13.30	33.77	39.95	12.97	6177.34	0.60
01	4454/17DUP	13.32	33.86	39.95	12.87	6197.61	0.63

Note: DUP - Duplicate

ANALYSTS

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Alemnesh Abate

QUALITY CONTROL

Awash Yerga



b

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Table 4.2. *Ultimate analysis result of Coal samples from Dawro-Tercha (%)*

Bed No.	C	H	O	N	S
S1BD4(1)	51.78				3.06
S1BD4(2)	73.45	6.21	18.25	2.14	0.43
S2BD1	56.15				1.36
S3BD4	62.47				0.08
S3BD5	67.30	5.54	23.26	1.78	2.13
S3BD1	79.80				0.82
S4BD2	81.14	5.43	11.14	2.48	0.46

Table 4.3. *Calorific Values & Carbon Contents of Coal samples from Dawro-Tercha*

Bed No.	Carbon content (%Wt)		Gross
	TC	TOC	GCV (kCal/kg)
S1BD4(1)	51.00	37.50	4116.00
S1BD4(2)	48.30	41.40	5850.00
S2BD1	-	-	-
S3BD4	52.00	38.30	3512.00
S3BD5	51.00	44.50	5615.00
S3BD1	51.00	62.30	-
S4BD2	51.00	67.10	6846.00

Table 4.1. *Proximate analysis result of Coal samples from Dawro-Tercha (%)*

Bed No.	Ash	Moisture	VM	FC
S1BD4(1)	59.18	5.01	34.77	24.79
S1BD4(2)	27.02	7.78	31.00	34.20
S2BD1	84.81	9.54	5.72	0.02
S3BD4	32.34	9.73	29.75	28.18
S3BD5	35.43	5.44	23.20	12.17
S3BD1	5.40	10.99	38.40	45.22
S4BD2	13.63	11.22	35.74	39.41

C

ET MINERAL DEVELOPMENT S. C. – Coal Processing Plant Feasibility Report



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Customer Name :- Mebratu Menu Issue Date:- 30/12/2024
 Sample type:- Coal Powder Request No:- GLD/RN/686C/24
 Sample Preparation:- 60 Mesh Report No:- GLD/TR/4214/24
 Date Submitted:- 12/12/2024 Number of Sample: One(01)
 Elements to be determined:- (Moisture, Volatile matter, Fixed carbon and Ash), Calories & Sulfur,
 Method of analysis:- Proximate Analysis, Adiabatic Caloric Metter and Gravimetric Method.

Collectors' Code	Moisture %	Volatile Matter %	Fixed carbon %	Ash %	Calorific Value cal/gm	sulfur%	Weight of Sample
TFB-1	21.54	31.41	34.14	12.90	4804.07	0.36	250gm

Note: - This result represent only for the sample submitted to the laboratory.

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Document Title:-	Hydrocarbon Analysis Report	Effective date:	Nov. 2022

Customer Name :- Berhanu Aberra Issue Date:- 30/12/2024
 Sample type:- Coal Powder Request No:- GLD/RN/685A/24
 Sample Preparation:- 60 Mesh Report No:- GLD/TR/4213/24
 Date Submitted:- 12/12/2024 Number of Sample: One(01)
 Elements to be determined:- (Moisture, Volatile matter, Fixed carbon and Ash), Calories & Sulfur,
 Method of analysis:- Proximate Analysis, Adiabatic Caloric Metter and Gravimetric Method.

Collectors' Code	Moisture %	Volatile Matter %	Fixed carbon %	Ash %	Calorific Value cal/gm	sulfur%	Weight of Sample
WC	6.55	32.39	37.46	23.60	5301.62	1.96	140gm

Note: - This result represent only for the sample submitted to the laboratory.

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Document Title:-	Hydrocarbon Analysis Report	Effective date:	Nov. 2022

Customer Name :- Berhanu Abera

Issue Date:- 30/12/2024

Sample type:- Coal Powder

Request No:- GLD/RN/685B/24

Sample Preparation:- 60 Mesh

Report No:- GLD/TR/4213/24

Date Submitted:- 12/12/2024

Number of Sample: One(01)

Elements to be determined:- (Moisture, Volatile matter, Fixed carbon and Ash), Calories & Sulfur.

Method of analysis:- Proximate Analysis, Adiabatic Calorie Metter and Gravimetric Method.

Collectors' Code	Moisture %	Volatile Matter %	Fixed carbon %	Ash %	Calorific Value cal/gm	sulfur%	Weight of Sample
FB	14.72	31.01	38.38	15.89	5311.59	1.50	100gm

Note:- This result represent only for the sample submitted to the laboratory.

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Document Title:-	Hydrocarbon Analysis Report	Effective date:	Nov. 2022

Customer Name :- Bethanu Abeta

Issue Date:- 31/01/2025

Sample type:- Powder /Coal

Request No:-GLD/RN/806/25

Sample Preparation:- 60 Mesh

Report No:- GLD/TR/4352/25

Date Submitted :-13/01/2025

Number of Sample: One(01)

Elements to be determined:-(Moisture, Volatile matter, Fixed carbon and Ash), Calories & Sulfur,

Method of analysis:- Proximate Analysis, Adiabatic Calorie Metter and Gravimetric Method,

Collectors' Code	Moisture %	Volatile Matter %	Fixed carbon %	Ash %	Calorific Value cal/gm	sulfur%	Weight of Sample
AFB	0.96	43.96	40.11	14.97	6540.27	1.40	90gm

Note: - This result represent only for the sample submitted to the laboratory.

Analysis

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