ADDIS ABABA INSTITUTE OF TECHNOLOGY

CENTER FOR ETHIO-MINES DEVELOPMENT

MASTER DEGREE IN MINERAL ENGINEERING

CHARACTERIZATION AND BENEFICIATION OF COAL BY FLOTATION IN SHEKA ZONE ANDIRACHA WOREDA SHEKIBADO KEBELE, SOUTH WEST ETHIOPIA

A project submitted to: Center for Ethio-Mines Development (CEMD) in Partial fulfillment of Master of Engineering in Mineral Engineering.

By: Temamen Gebo

Advisor : Melesse Alemayehu (PhD)

Co. Advisor : Abinet Markos (MSC)

May ,2025G.C

Addis Ababa, Ethiopia

ADDIS ABABA UNIVESITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
CENTER FOR ETHIO-MINES DEVELOPMENT

APPROVAL SHEET

This project entitled "Study on "CHARACTERIZATION AND BENEFICIATION OF COAL BY FLOTATION, IN SHEKA ZONE, ANDIRACHA WOREDA, SHEKIBADO KEBELE, SOUTH WEST ETHIOPIA" is prepared by Temamen Gebo, which is submitted in the partial fulfillment of the requirement for the degree of master of engineering in mineral process compiles with the regulations of the university and meets the accepted standards with respect to originality and quality.

Signed by the Examining committee:	Signature	Data
Advisor:		
Dr. Melesse Alemayehu	____________	____________
Co- advisor:		
Abinet Markos (MSc)	____________	3/08/2017 E .C
Internal Examiner:		
Dr. Melesse Alemayehu	____________	____________
External Examiner:		
	____________	____________
Chair Person:		
____________	____________	____________

DECLARATION

I hereby declare that the project entitled **''Characterization and beneficiation of coal by flotation, in Sheka zone, Andiracha woreda, Shekibado kebele, South west Ethiopia''** is prepared by Temamen Gebo, with the guidance of my advisor Dr. Melesse Alemayehu. The work contained herein is my own, except where explicitly stated otherwise in the text /journal and that this work has not been submitted, in whole or in part, for any other degree or professional qualification.

Author	Signature	Data
Temamen Gebo	______________	______________

ACKNOWLEDGEMENT

First and foremost, I am deeply grateful to the Almighty God for granting me the strength and good health to complete this work. In particular, special thanks to my advisor Dr. Melesse Alemayehu and co-advisor Mr. Abinet Markos for their guidance and experience support throughout my project .I would like to thank Mr. Mebratu Menu, Mr.Wondishaw Wosen, who supported me during my project. Also, I would like to thank the AAiT, School of Chemical and Bio-Engineering, mechanical operation laboratory instructors Mr. Hintsasilase Seifu, who helped me during experimental work.

Moreover, I thank the Center for Ethio-Mines Development (CEMD) for sponsoring study and giving me the opportunity to study at Addis Ababa University, institute of technology.

ABSTRACT

This project successfully characterized and beneficiation by flotation of the coal founding in Sheka Zone Andiracha Woreda, using the proximate analysis and calorific value analysis method for coal detection and evaluation. The study focuses on the characterization and beneficiation of coal using proximate analysis and flotation methods. The parameters for flotation test method are affected by a number of physical and chemical factors, including type and dosage of reagents, pulp, particle size, impeller speed, froth depth, among many other during laboratory experiment. The flotation process can be done with the collector dosages (5ml to 10ml), frother dosages (2ml to 4ml) and particle size (-250 µm +125µm -75µm). Proximate analysis after and before treatment, which includes moisture, ranges from 5.27% to 13.64%, ash content range from 41.15% to 47.69%, volatile matter content ranges from30.46% to 23.46%, and fixed carbon content ranges from 23.13 to 15.22%, is essential for determining coal quality. The calorific value is most crucial component to determine the grade coal which is before flotation value 4002.21BTU/Ib and after flotation value is 6587.05BTU/Ib. The analysis highlights the relationship between coal ranks and calorific value, a critical indicator of energy efficiency and economic potential. By combining proximate analysis with optimized flotation processes, the study provides insights into enhancing the economic and environmental performance of coal from the study area.

Key words*:* coal character, coal flotation, operating factor, and calorific value

CONTENTS

LIST OF FIGURE

LIST OF TABLE

LIST OF ABBREVIATION AND ACRONYMS

AC -- --Ash content

ASTM---------------------------------------American society of testing material

BTU/Ib--------------------------------------British thermal unit per-pound

CV--Calorific value

Cal/g ---------------------------------------Caloric per- gram

D.m.m.f------------------------------------Dry mineral matter free

EMDC--------------------------------------Ethio- mines development center

FC-- Fixed carbon

GPS --Geographical position system

Kg---kilogram

MC --Moisture content

ml--Milliliters

M. m.m-free--------------------------------Moist mineral matter free

PH ---Power of Hydrogen

VM --Volatile matter

µm --- Micrometer

CHAPTER ONE

1. INTRODUCTION

1.1 Back ground

Coal is a fossil fuel formed from plant remains preserved through wood and mud conservation, influenced by oxidation and biodegradation (Kebede & Cheepurupalli, 2019). The coal industry primarily serves two main markets: thermal coal, which is used for energy production, involving the generation of power and industries like cement manufacturing, and metallurgical coal, which is mainly utilized in steel production. Additionally, coal has other uses, for example being converted into gas or processed into energy creation or chemical manufacturing (Osborne & Gupta, 2013). When choosing coal for a specific application, several chemical and physical properties must be considered, including heating value, fixed carbon content, ash melting temperature, sulfur content, impurity levels, and mechanical strength (Kebede & Cheepurupalli, 2019). According to this specification application coal is most used in industrial sector. Coal is one of most important energy resources. The coal deposits have their own specific characteristics, whereas the mineral components associated between mineral matter and organic matter. Proximate analysis of coal is a test used to determine the composition of coal based on several key components. It provides an approximate measure of the coal's quality and potential use. The analysis typically includes four main components like moisture content; ash content, volatile matter and fixed carbon content are important determined factor for quality of coal in specific environmental deposition. The calorific value of coal (also called heating value or energy content). It is a key indicator of coal's quality and its ability to produce energy. To meet the energy requirement needs successive studies from beginning of field of exploration up to the plant industries.

Ethiopia's coal deposits are primarily from the Tertiary period, with smaller amounts dating back to the Mesozoic era, several geochemical studies have been conducted to analyze the physio-chemical properties of these coal reserves, Based on their origin, the coal seams are classified into humic, sapropelic, and mixed types(Ahmed, 2008). Coal seams located near acidic volcanic intrusions have undergone metamorphism to a semi-anthracite stage due to a high geothermal gradient. The moisture content varies between 2.7% and 21.4%, volatile matter ranges from 3.0% to 46.3%, ash content falls between 2.4% and 65%, and the calorific value spans from 900 to 6900 Cal/g (Ahmed, 2008). To this specific type and origin of coal of Ethiopia have low quality. Due to this low quality there is need deep knowledge for coal characteristics and beneficiation by flotation needed for quality increment .According to this research the further study can be conducted by characterization and beneficiation of coal by flotation method to increase the quality of standards. Ethiopian cement industries mostly imported coal from foreign country product ,while the cost of the product are increasing from year to year it can result imbalance between import and export that directly affect economy of our country. According to this it is reduced import products and they may be contributed for our country economic developments.

Froth flotation is a widely used technique for cleaning fine coal, utilizing the differences in surface properties between organic and mineral matter. Organic matter, particularly in bituminous coal, is hydrophobic and less prone to wetting than mineral surfaces. In a flotation unit, clean coal particles with minimal mineral content adhere to rising air bubbles and float to the surface, while mineral-rich particles, which are more easily wetted, sink and are removed. To enhance process efficiency, parameters such as pulp density, pH, rotation speed (r/min), coal particle size, and the dosages of collector, frother, and conditioner must be optimized and their interactions evaluated to achieve the desired ash removal and concentrate recovery (Jorjani et al., 2008). This a good coal flotation operation factor indicates that the flotation process is effectively separating valuable coal from impurities, resulting in a cleaner, higher-quality product with higher recovery rates and efficiency. The coal flotation operation factor refers to a key parameter in the flotation process, a method applied to separate valuable coal particles from unwanted materials (such as ash, sulfur, and other impurities) by utilizing change in their surface characteristics. The present project study has important play role in characterize and coal beneficiation by flotation.

1.2. Location and Accessibility

Sheka zone is situated in the South West Regional State of Ethiopia. It shares borders with Bench Maji to the south, the Gambella Region, to the west, the Oromia Region, to the north, and Keffa to the east. The administrative capital of Zone is Teppi. Sheka was previously the western part of former Keficho Shekicho Zone. The Zone lies approximately 650 kilometer Southwest of Addis Ababa. The study area is the located under the administrative town of Teppi approximately 75 kilometer found, in Andiracha Woreda Shekibado kebele (fig.1).

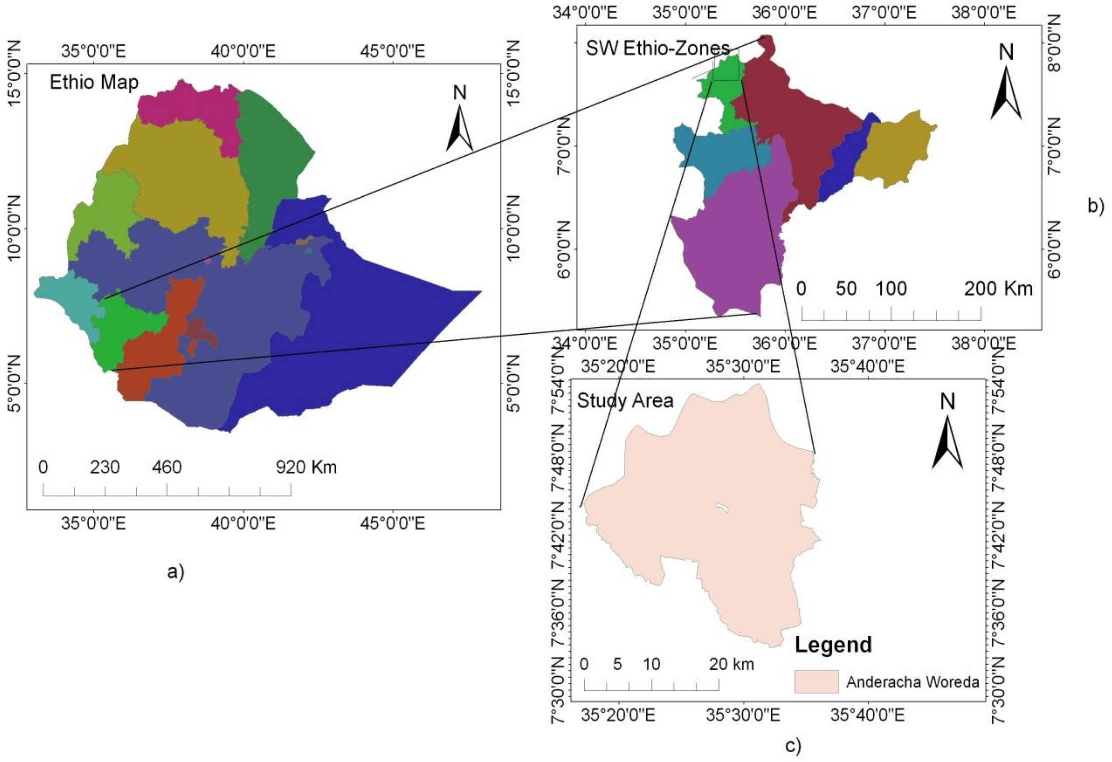


Figure 1: map of (a, Ethiopian regions, b, south west Ethiopia, c, study area).

1.3 Statement of Problem

The availability of coal resource is high in the country Ethiopia, but the study is very poor and there is no further investigation to identify the resource the coal availability and the types of reserves present in the country Ethiopia. There are also our country some investigated coal are low quality due to the high ash, low fixed carbon and low calorific value according to (Ahmed Wolela ,2008), which needs more treatment before utilization. So Ethiopia can import coal from foreign country to fulfill the company need, that directly affects in economic imbalance and pay huge expense.

Coal mineral is considered global key energy sources for different companies like cement, steel, fertilizer production and coke production. Today the country Ethiopia can pay huge amount of foreign currency to fulfill the domestic industry needs like cement.

Therefore, to solve the above mentioned problem this project can upgrade coal resources availability and what type of coal are presents in this study area, but also they can what type of beneficiation technology is needed. Flotation process technology is upgrades the quality of coal that can be fulfilling the industry needs of our country. Coal helps generate energy and is used to manufacture like cement and reduce import of coal from foreign country and currency expense. This project has been characterization of coal and beneficiation of coal by flotation techniques to reduce the poor quality of coal and meet industrial standards of our country company requirement**.**

To sum up all, the following quaternaries are listed below

- What is the amount of proximate analysis and thermal energy (calorific value) released from coal BTU/Ib in study area?
- What type of coal is present in that study area?
- What parameters are suitable for coal beneficiation by flotation process to improve quality?

1.4 Objective

1.4 .1 General Objective

The main objective of the study is a characterization and beneficiation of coal by flotation in study area.

1.4.2 Specific Objectives

- To identify proximate analysis and amount thermal energy (calorific value) released from coal BTU/Ib in study area.
- To analyze types of coal present around study area.
- To determine coal beneficiation by flotation parameter to improve quality.

1.5 Significances of the Study

The importance of this project is multifaceted, with implication for economics, environmental scientific, technological and corporate aspects.

Economic significance: The coal is to contribute major energy resources of our country like for cement industry.

Environmental significance: Coal Company processes a major contributor of environmental impact and to come up with some techniques for further mitigation measures to eliminate the negative impact.

Scientific Significance: This project contributes to the scientific understanding of the beneficiation of coal by flotation processes and physiochemical properties. The result can inform future research on coal beneficiation and improve our understanding of the behavior of parameter like particles size, reagent impeller speed during flotation process**.**

Technological significance: beneficiation by flotation and characterization techniques has the potential to apply on industrial scale for upgrading low grade coal. This is expected to improve insight in to optimal conditions for the process, leading to the development of effective and efficient technology for coal beneficiation process

1.6 Scope of Study

The scope of the study covers the characterization and beneficiation of coal by flotation in the study area of Sheka zone Andiracha Woreda Shekibado Kebele to determine coal type around that area and uses of that coal is used in energy production sectors. At times, the quality of coal meets industry requirements across various companies in our country. In coal beneficiation through flotation, laboratory experiments are conducted to ensure it meets the necessary quality parameters.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. GENERAL OUT LINES OF COAL

Coal is a fossil fuel that has been mined for centuries in various parts of the world. It served as the main energy source from the 18th century until the 1950s. Coal remains a crucial energy source for many countries worldwide and will continue to hold its importance for a long time due to its consistent demand and supply (Yilmaz, 2021). Today, coal is mainly utilized as a combustible solid energy sources generate power and heat generated by burning, as well as in a range of industrial processes. Coal is a complex and heterogeneous material composed of several distinct organic components, called macerals, along with different amounts of inorganic (Xie, 2015a).By the time coal extracted and used for most energy sources and used in technological advancements. Flotation process is most recent technology for the recovery and upgrade of coal quality. When the ASTM standardization method can develop our country coal types and identify technological usage advancements. This study is particularly observed the information of coal process in area. One of the initial methods for determining mineral matter involved calculating its percentage based on the coal's ash yield and the presence of additional important inorganic compounds found in the Coal (Ward, 2002).Then ash yield calculation is most important parameter for determined coal and other mineral component . Coal is classified into four ranks, arranged from highest to lowest. These are anthracite, bituminous coal, sub-bituminous coal, and lignite. Generally, anthracite and bituminous coal are considered higher ranks, while sub-bituminous coal and lignite are categorized as lower ranks (Liew et al., 2021).This Coal plays a crucial role in various industries due to its versatility as a fuel and raw material:

Coal plays a vital role in various industries due to its high energy content and versatility. In electricity generation, it serves as a primary fuel in power plants, where it is burned to produce steam that drives turbines, converting thermal energy into electricity. The cement industry relies on coal as an energy source to heat kilns, facilitating the transformation of limestone into clinker, the key component of cement. In the metal refining industry, coal is essential for steel production, where it is used to produce coke, a crucial reducing agent in blast furnaces for extracting iron from its ore. Additionally, the fertilizer industry utilizes coal as a source of heat and hydrogen in ammonia production, a critical component of nitrogen-based fertilizers.

2.1.1. Coal formation

Coals A sedimentary rock of organic origin that originates that forms over millions of years that the remains of dead plants(Wakuma & Assaba, 2017) .this plant material accumulates in thick layer ,becoming buried by water or sediment.

2.1.2 Classification of Coal

Coal is categorized based on the transformation it has undergone from peat to anthracite; the quality of coal depends on the temperature, pressure, and duration of its formation (Pudasainee et al., 2020). Coal reserves mostly consist of that is known humic Coal. Humic coal capable of being categorized classified as peat, lignite, bituminous coal, and anthracitic coal, based on the stages of the coalification process (Xie, 2015a).This classification of coal is based on the its rank, which depends based on the level of coalification the process of transformation from plant to coal. In ASTM standards the grade of coal is standardize according to the degree of mineral alliteration from lignite to anthracite. The primary criterion in the ASTM classification system is the dry, mineral-matter-free volatile matter, which is essentially equivalent to fixed carbon (calculated as 100 minus the volatile matter) (Oni et al., 2017). This ASTM classification system is most used in industrial sector of worldwide basis.

Peat

Peat is the initial stage in coal formation. It is a soft, crumbly, dark brown substance that develops over generations from decomposing and partially decayed organic matter (Jovanovski et al., 2023).

Lignite

Lignite is soft, brown, and crumbly materials with a dull, earthy look, they contain a high amount of oxygen (up to 30%), a relatively low carbon content ranging from 60 to75% when dry, and a moisture content ranging from 30% to 70% (Pandit et al., 2011).It is formed from peat by coalification process and low carbon content relative to bituminous.

Bituminous Coal

Bituminous coal, also referred to as soft coal, is widely used in industries as a fuel source and contains no traces of plant material (Xie, 2015b).

Anthracite

The highest quality coal is hard, glossy, and black, with a carbon content of 86-97%. It has the highest calorific value and is primarily used for heating in residential and commercial spaces (Mathu & Chinomona, 2013). Because of its high quality, it burns without producing smoke.

Coal is composed of a combination of organic and inorganic materials, with moisture content also playing a significant role. The organic portion of coal is made up of different maceral components, each contributing to its properties and energy content. Vitrinite, the carbon content of vitrinite increase and oxygen content of vitrinite decrease(Li et al., 2010). Is the most common maceral and significantly contributes to coal's heat value because, of the high level of carbon content and combustibility. Liptinite, which resinous plant material composed of spores, cuticles, and pollen, has a significant amount of hydrogen and produces volatile gases when heated, influencing the coal's volatility (Scott, 2002). Lastly, inertinite, which is derived from oxidized plant material, is more carbon-rich and less reactive than vitrinite and liptinite(Xie, 2015b). It is also more resistant to combustion, making it less energy-efficient. The proportions of these macerals determine coal's energy content, combustion characteristics, and volatility.

Table 1: Classification of coal by grades Source: 2000 annual book of ASTM Standard.

Class	Group	Fixed carbon, %(dry mineral matter free basis		Volatile matter % (dry mineral matter-free basis		Calorific value Btu/lb(moist mineral matter free basis	
		Equal (greater than	Less than	Greater Than	Equal Less than	Equal (greater than)	Less than
Anthracite	1.Meta-anthracite	98	---	---	2	---	---
	2. anthracite	92	98	2	8	---	---
	3.semi anthracite	86	92	8	14	---	---
Bituminous	1.low volatile bituminous	78	86	14	22	---	---
	2.Medium volatile bituminous	69	78	22	31	14000	---
	3. high volatile A bituminous	---	69	31	---	13000	---
	4. high volatile B bituminous	---	---	---	---	11500	14000
	5. high volatile C bituminous	---	---	---	---	10500	13000
Sub Bituminous	1.Sub Bituminous A	---	---	---	---	10500	11500
	3. Sub Bituminous B	---	---	---	---	9500	10500
	3. Sub Bituminous C	---	---	---	---	8300	9500
Lignite	Lignite A	---	---	---	---	6300	8300
	Lignite B	---	---	---	---	---	6300

.

2.1.3 Coal Deposits in Ethiopia

Inter-Trappean coal deposits in Ethiopia are located across the South-Western and Central Plateau regions, including areas such as Delbi-Moye, Yayu, Lalo-Sapo, Sola, Chida, Chilga, Nejo, and the Mush Valley Basins(Ahmed, 2008). The coal-bearing sediments were formed in fluvial, lacustrine, and paludal depositional environments. Palynological studies have confirmed that these sediments date back to periods ranging from the Eocene to the Miocene. Ethiopia's total registered coal deposits amount to 297 million tons (Ahmed, 2008).Proximate analysis and thermal value assessments show that Ethiopian coal deposits range from lignite to bituminous coal. However, coal seams found near acidic volcanic intrusions have been transformed to a semi-anthracite stage due to the influence of a high geothermal gradient.

Table 2: Coal deposit in Ethiopia Source: modified from (Wolale Ahmed, 2008).

Basin	Depth in Meter	Thickness in meter	Moisture in (%)	Volatile matter in (%)	Fixed carbon in (%)	Ash in (%)	Calorific value in (cal/g)
Delbi-Moye (Eastern block)	Outcrop	1.0	5.58	29.0	49.1	11.9	6495
	50.8	1.4	4.0	26.3	47.1	22.7	2520
Yayu (Wittete Block)	Outcrop	4	18.6	28.3	28.5	24.6	3795
	90.8	1.54	8.1	44.9	14.5	42.1	5605
Chilga	Outcrop	0.7	5.9	21.1	34.4	39.5	3072
	35.7	0.6	7.3	22.9	38.2	41.6	4441
Lalo-Sapo	Outcrop	2.0	13.4	32.4	20.9	33.1	4120
	Outcrop	1.0	12.0	18.2	58.3	11.5	4015
Chida	Outcrop	1.0	11.2	15.0	51.0	22.8	2492
		1.5	18.9	27.6	22.4	33.5	4333
Mush valley	Outcrop	1.8	21.3	31.8	27.9	19.0	2824
Nejo	Outcrop	0.5	16.0	35.2	28.8	23.1	3400
		1.0	14.4	30.5	35.5	19.6	3987
Wushale	Outcrop	0.5	10.4	18.0	45.4	35.2	3700
		0.4	12.3	29.7	22.6	48.7	5445

2.1.4 Characterization Process

Proximate and ultimate analysis: Proximate analysis was conducted to determine the percentages of ash, volatile matter, moisture, and fixed carbon in the feed. Meanwhile, ultimate analysis was carried out to measure the constituents elements found in coal, specifically the percentages of carbon (C), hydrogen (H), nitrogen (N), and sulfur (S) (Sahu et al., 2019).proximate and ultimate analysis key parameters for characterization of coal.

2.1.5 Distributed phase in coal flotation

Flotation pulp consists of three dispersed phases: includes coal fines, dispersed oil , and gas bubbles, Various factors influence the sub-processes and the overall efficiency of the flotation process, including material properties, chemical conditions, operational settings, and equipment parameters (Polat et al., 2003). The parameters must need adjustment for better yield during flotation process. Froth flotation takes advantage of the differences in surface hydrophobicity between various minerals, allowing for the selective separation of valuable minerals from gangue. The valuable minerals attach to air bubbles and are then recovered from the froth containing the mineral particles (Han et al., 2014). These valuable minerals adhere to air bubbles and are subsequently collected from the froth, which may contains the mineral particles. Kerosene was used as the collector, while fusel a frother mixture containing propanol, butanol, and pentanol from alcohol production byproducts—served as the frother. A series of batch flotation tests were conducted to optimize the impeller rotation speed, as well as the dosages of the collector and frother, various physical and chemical factors influence coal flotation kinetics and the flotation rate constant, including reagent type and dosage, pulp pH and density, particle size, gas flow rate (superficial gas velocity), bubble size, temperature, impeller speed, froth depth, and flotation cell design, among others (Wang et al., 2018). This design criteria used when air is injected in to the mixture, the hydrophobic coal particles attaches to the bubbles and floating upward to be collected. Froth flotation is a process used to separate minerals with significantly different wettability by employing a surface-active agent that stabilizes the froth formed on the surface of an agitated water suspension of the material (Meshram et al., 2015). Froth flotation is a process used to separate valuable minerals from waste material in an ore. It works by adding chemicals and air to a slurry of finely ground ore and water. The chemicals help the valuable minerals attach to air bubbles, which rise to the surface and form a froth.

2.2 Regional Geology lithology and Tectonic

The Precambrian rocks of Ethiopia, which serve as the foundation for younger sedimentary and volcanic deposits, are visible in various parts of the country. These exposures are found in east-central (Harar), west-central (Gojam and Wellega), northern (Gondar and Tigray), and southern (Sidamo, Bale, and Illibabore) regions. They are primarily located in peripheral areas where erosion has removed the overlying younger rock layers (Walle et al.). When in this area of most part of illibabore most of time soil is eroded by strong rain activity in the environment.

Ethiopia, two distinct different forms of coal-bearing sedimentary deposits has been identified: (i) sandstone–coal–shale facies and (ii) siltstone/mudstone–coal association shale formation. The coal seams within the sandstone–coal associated shale formations are generally thicker and more continuous compared to those found in the siltstone/mudstone–coal–shale facies. Large coal deposits are present in the Delbi-Moye, Chilga, Yayu, Lalo-Sapo, Nejo, Wuchale, and Mush Valley Basins according to Wolela Ahmed 2007. In Sheka Zone the area is similarity of lithology characteristics according to the regional location that fund in study area. Because, of the geological settling similarity. Western Ethiopia's geology features diverse rock types spanning from the Precambrian to the Quaternary period. The region's Precambrian basement, stretching northward from 6°N for approximately 650 kilometers, represents the largest Precambrian formation in Ethiopia according to Tadesse Alemu geology of Arjo area.

The Cenozoic rock formations in southwestern Ethiopia exhibit both pre-rift and post-rift sequences. The landscape is largely dominated by Tertiary lava flows, pyroclastic deposits from flows and fallouts, ash flows, as well as minor Quaternary ash falls and alluvial sediments(Abebay et al., 2024).

2.3 Local Geology

Generally the study areas are rich in construction and industrial mineral such as basalt Rhyolite, trachyte, diorite, and granodiorite, along with sandstone and various metamorphic rocks exhibiting a range of metamorphic grades from schist to gneiss. Coal rich sedimentary formation minerals have high like, siltstone, clay stone, mudstone and fine grained sand stone in study area.at Delbi Moye ,Chilga,Yayu Lalo-Sapo,Nejo,Wuchale Much valley bassins that are active mine coal operation currently going and study past decayed years by (Wolela Ahmed2007) .Study area are have fine grained sand stones which shows the major presence of clay minerals. From figure three shown in study area the sedimentary characterization have structure of horizontal and ripple marks shows coal seams have alternation after depositional on the environment. Additionally, the coal seams contain highly organic rich sediments, including humic coal beds and clay stone, which are widely distributed throughout the area.

2.4 Climate and vegetation

2.4.1 Climate

The climate falls under warm subtropical climate condition. The dry season in this area from December to January and the rainiest seasons from June to September also other season are little rainy season. The region experiences abundant rainfall, varying between 1000 mm and over 2200 mm per year, with daily temperatures averaging between 17°C and 21°C(Tesfu & Dawit Habte, 2021).

2.4.2 Flora and fauna

Majority part of the south west region is covered by coffee and forest. Wheat, maize, barely, inset, potato and others are edible by the inhabitants of the area and cover wide hectares of land. The types of vegetation in study area are acacia; eucalyptus, trees and forest (wooded area) along the side of major river. The wildlife and domestic life distributed animal like Lion, Hyena, Antelope, gureza, Monkey, Dikula. Midakuwa, Ape, Goat, cow and Sheep are also available in the area. Despite their rich biological diversity, several tropical biosphere reserves, including Sheka, Majang, Kafa, and Yayo, host a wide range of biological species and provide various ecological services. These regions are home to diverse plant species, including coffee, spices, and medicinal plants. The most effective way to conserve biodiversity in these areas is through the protection of entire biosphere reserve ecosystems

CHAPTER THREE

3. METHODS AND MATERIALS

3.1. MATERIALS

3.1. 1.Apparatus and Instruments

The equipment and tools utilized in this investigation included; All-Purpose Hot Oven, weight balance, Air Compressor, scraper, desiccator, crucible, muffle furnace, Jaw crusher (RoHs53743, Deutschland), Centrifugal grinder (RETCH 56402, Deutschland), Sieve Vibrator (RETCH A200, Deutschland), Wedag flotation unit (Groppel 98, West Deutschland)shown (fig.2).

Figure 2: instrument used during the project activity.

3.2 Chemicals and Reagents

During the flotation of coal samples, various chemicals and reagents are used to enhance the separation of coal particles from impurities by modifying their surface properties. During the study of this project kerosene are used for collector and n- octanol for frother. It should be noted that laboratories experimental reported for the use of reagents**.** These reagents are selected and dosed based on coal type, ash content, and the desired separation efficiency. But in this study should be done with the availability of chemical and reagent in market.

Material

Samples of Coal were taken from seams at depths, ranging from 0.5 m to 1 m. The samples were taken from freshly exposed coal surfaces. The coal samples located in the south west region in sheka zone Shekibado kebele shown (fig.3).

Figure 3: coal sample taken from location

3.2 Method of Characterization

3.2.1 Proximate Analysis

Determine the moisture, volatile matter, ash, and fixed carbon content using standard proximate analysis techniques. The proximate analysis is used to determine moisture content, volatile matter, ash content and fixed carbon of coal based on American Society for Testing and Materials (ASTM). The proximate analysis of coal aims to assess its characteristics and quality for practical use by determining the relative proportions of total moisture (TM), volatile matter (VM), fixed carbon (FC), and ash content (ASH) present in the coal. The proximate analysis serves as the fundamental test for evaluating coal quality (Widodo et al., 2020).

3, 2.1.1 Moisture content analysis

Moisture content is measured known value is heating, a coal sample at a low temperature (around **105°C to 110°C**)for 30 minutes and the dried on hot oven was cooled by in a desiccator, and then weighed .

Moisture content procedure; calculated as the following

$$M\% = \frac{w2-(w3-w1)}{w2} * 100\% \text{ -------------- } (3.1)$$

Where, w_1 -Mass of dish (g)

w_2 - Mass of sample (g)

w_3 -Mass of dish after drying (g)

Figure 4: Determination of moisture

3.2.1.2 Volatile matter analysis

Volatile matter is determined by heating a known amount of coal in a covered crucible at a specific temperature (usually **900°C ± 10°C**) for a fixed duration (usually **7 minutes**) in the absence of air.

$$\text{Volatile matter } \% = \frac{\text{Weight Loss (excluding Moisture) (g)}}{weight\ of\ orgional\ sample\ (g)} * 100\ \% \text{--------------------} (3.2)$$

3.2.1.3 Ash content analysis

Ash content refers to the incombustible material remain after the combustion of coal. It represents the inorganic minerals present in coal, such as silicates, aluminates, and oxides of iron, calcium, and magnesium. Determining ash content is an important step in evaluating the quality of coal because it directly affects its efficiency, calorific value, and handling properties**.** First dry clean crucible was dried then the clean known amount of coal sample such as powder form is added to the crucible in a muffle furnace and heated it to 750°C for 2 hours.

Ash analysis procedure; calculated ash content by the formula Ash percentage,

$$A\% = \frac{M3-M1}{M2} * 100 \% \quad \text{--------------------------} \quad (3.4)$$

Where, M_1 -Mass of crucible (g)

M_2 - Mass of sample (g)

M_3 -Mass of crucible with ash (g)

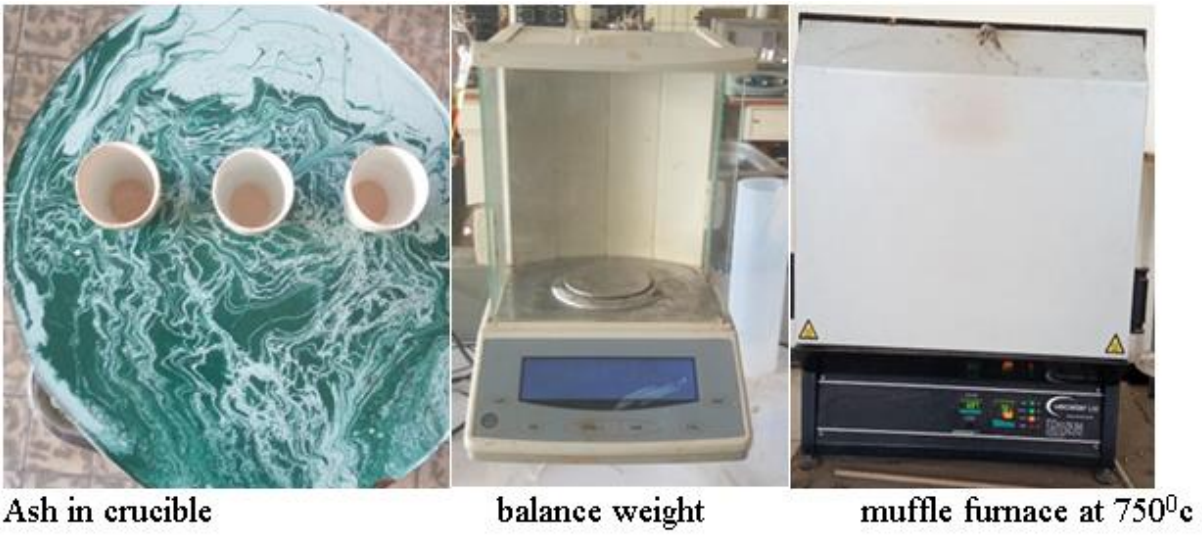


Figure 5: Determination of ash.

3.2.1.4 Fixed Carbone analysis

It is determined by subtracting the sum of all the above parameters and is given as Fixed Carbon, FC = 100 - (M + V + A) ------------------------- (3.3)

Where, M -Moisture content V - Volatile matter content A -Ash content

% ash in coal = {wt. of residue ash formed X 100} / wt. of coal initially taken.

3.3 Calorific Value Analysis

The **calorific value** (CV) of coal, also which also termed as its heating value, is the amount of emitting energy triggered by a given quality of coal fully combusted. It is a critical parameter used to evaluate coal’s efficiency and suitability for various industrial applications, such as power generation, steelmaking, and cement production. The calorific value of a known measured coal sample was determined by burning it in a bomb calorimeter filled with oxygen. The temperature rise of the water bath and the calorimeter’s water equivalent were used to calculate the heat released during combustion. The calorific value or heat of combustion or heating value of a sample of fuel is defined as the amount of heat evolved when a unit weight (or volume in the case of a sample of gaseous fuels) of the fuel is completely burnt and the products of combustion cooled to a standard temperature of 298^{o}K. The calorific value of coal is calculated by using the relation.

Calorific value = ((Tf – Ti) * Water equivalent) / Weight of the pellet ------------- (3.5)

Where, Tf – Final temperature Ti – Initial temperature Useful heat value = 8900 - 138(A+M).

3.4 Determination of Sulfur Procedure

Known quantity of coal is heated with Eschka mixture (which consists of 2 parts of MgO and 1 part of anhydrous Na_2CO_3) at 800˚C.After burning amount of sulphur present in the mix is retained as oxides and it is predicated as sulphates. The sulphate formed is precipitated as $BaSO_4$ (by treating with $BaCl_2$)**: Percent of sulfur**=100*0.1374 * $\frac{Y}{X}$**, --------------------** (3.6)

Where, X = weight of coal sample taken and Y = Weight of BaSO4 precipitate formed.

3.5 Coal Grade Determination

Coal grade determination; refers to the process of evaluating and classifying coal based on its quality and properties, which influence its suitability for various applications. The ASTM classification system is commonly used for coal grade determination. In the ASTM classification system, the primary criteria used are the fixed carbon content and the calorific value, both calculated on a mineral-matter-free basis.

Parr formulas shown below,

Dry m. m- free FC = $\frac{FC}{100-(M+1.1*A+0.1+S)} * 100\%$---------------------- (3.7)

Dry m.m-free V.M = 100- Dry m.m – free FC% ------------------------------ (3.8)

Moist m.m-free Btu = $\frac{BTU}{100-(M+1.1*A+0.1+S)} * 100, per\ Ib$--------------------- (3.9)

Where:

M-M = mineral matter

Btu = heating value per lb

FC = fixed carbon, %

VM = volatile matter, %

M = moisture, %

A = ash, %

S = sulfur

3.6 Sampling Techniques

The techniques used to collect samples from the study area according to guidelines of the International standards of coal analyses (ASTM). Coal sampling locations at GPS position of p1; x (Easting) 745359, y (Northing) 852323 p2; x (Easting) 749886, y (Northing) 851706 p3; x (749249), y (848789), p4; x (745105), y (849493) and the coal sample were collected in three different area by plastic bags approximately an amount of 10kg.

3.7 Sample Preparation

Sample preparation is conducted prior to the analysis phase to ensure samples are prepared according to the required parameters. The preparation process in this project involves steps such as cleaning, size reduction, and sieving (Widodo et al., 2020). The process of sample preparation was carried out at the addis ababa university institute of technology laboratory. The size categories -500 +250 μm, -250 +125 μm, and -75μm. The coal samples collected from the research area were prepared following ASTM guidelines. The course coal, containing organic matter, mineral (inorganic) components, and inherent materials, was pulverized for further processing.

3.8 Flotation Test

The flotation tests were conducted in flotation unit. The initial coal sample weight was 95g, which was added to 2L of water in 3L flotation cell, followed by the addition of desired volume of solutions for frother and collector. The pulp was stirred at an impeller speed of a set of 1500 rpm for 3 minutes, followed by an additional 2 minutes of gentle agitation to facilitate the attachment of the collector to the coal surface. After conditioning, air was introduced into the flotation cell to produce froth, which was continuously skimmed from the top of the cell every 15 seconds over total flotation duration of 10 minutes.

$$\text{Recovery }\% = \frac{mass\ of\ desired\ mineral\ in\ concentrate}{mass\ of\ desired\ mineral\ in\ feed\ stream} * 100\ \% \text{ ------------ } (3.10)$$

$$\text{Yield }\% = \frac{mass\ of\ concentrate}{mass\ of\ feed} * 100\% \text{ ------------------------ } (3.11)$$

$$\text{Grade }\% = \frac{mass\ of wanted\ material\ in\ \ stream}{mass\ of\ stream} * 100\% \text{ ------------------------ } (3.12)$$

Flotation Index (FI) = Grade * Recovery ------------------------------- (3.13)

Figure 6: Flotation Experiment.

3.9 Experimental Design

The research provided a detailed description of all the experimental methods performed according to figure behind. The techniques of sample arrangements were conducted in following phase of analyses.

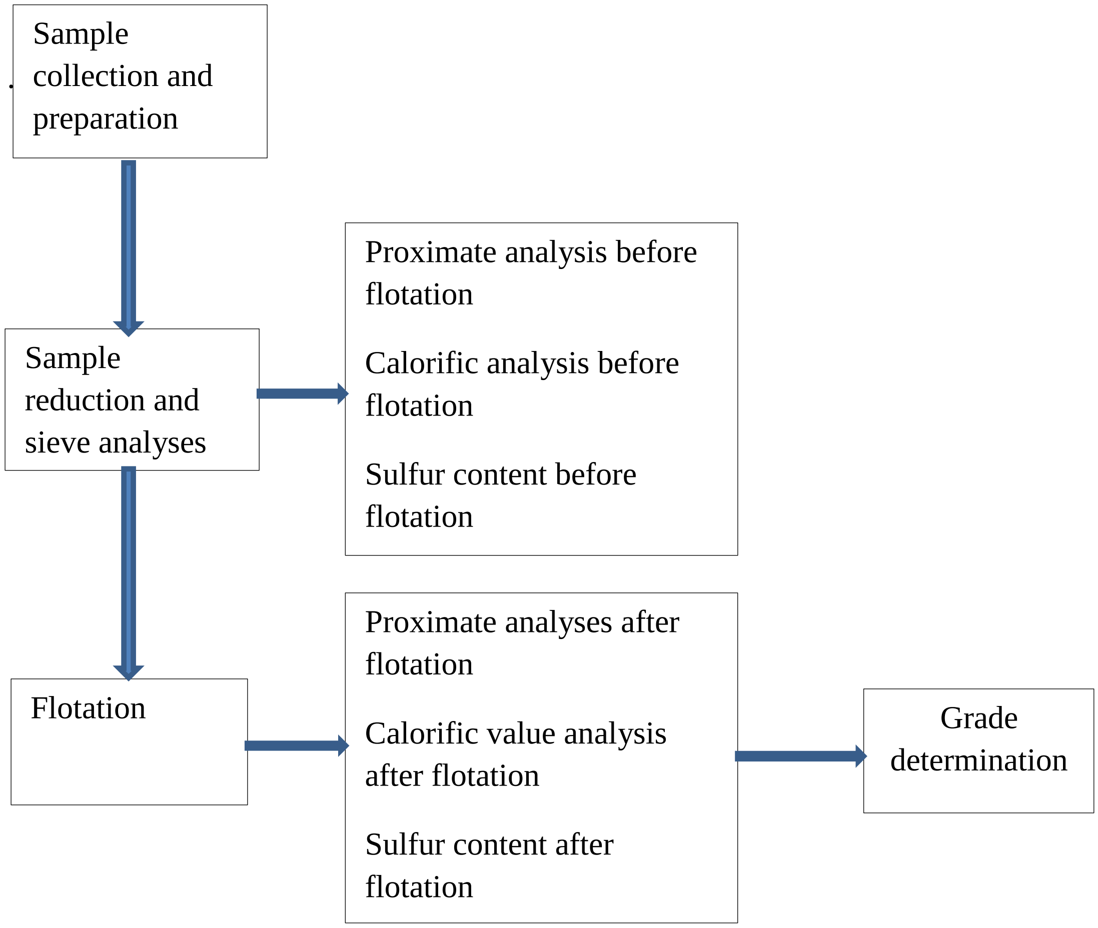


Figure 7: Over all experimental design from beginning to end

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 .Proximate analysis

The proximate analysis result of before flotation and after flotation, such as moisture content, volatile matter, ash content and fixed carbon are shown in table three.

Table 3: Proximate analysis before flotation and after flotation

	Before flotation	After flotation
Ash %	47.69	41.15
Volatile matter %	23.46	30.46
Moisture content %	13.64	5.27
Fixed carbon %	15.22	23.13

.

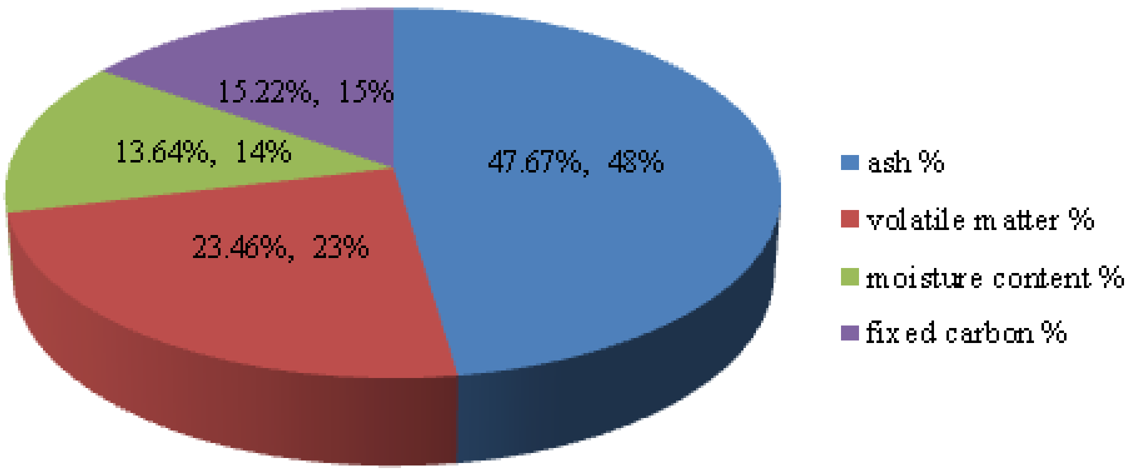


Figure 8: Proximate analysis before flotation.

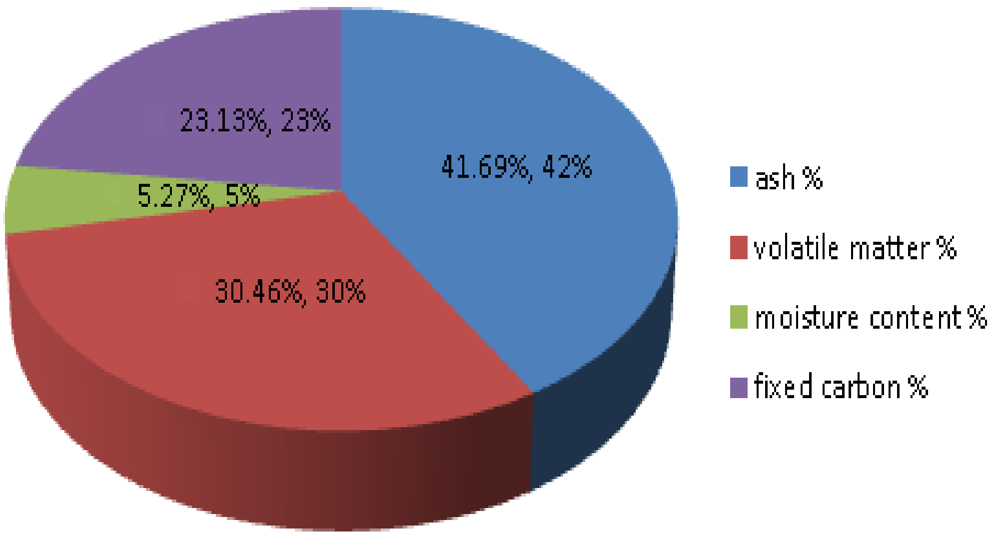


Figure 9: Proximate analysis after flotation.

4.1.1 Moisture Content

When coal is gently heated to a temperature just above the boiling point of water, it loses weight due to the release of moisture. The moisture content in coal can vary significantly, ranging from around 5% to nearly 70%. This moisture is undesirable because it lowers the coal's heating value (since water cannot combust) and increases transportation costs due to the added weight (Wakuma & Assaba, 2017).The moisture components of coal samples varies from 13.64% to 5.27% then the coal indicates undesirable this indicated the coal is low rank. But the moisture content after flotation is 5.27% this indicates that the flotation is decreased and effective. Because of high moisture ash and slime particles flotation effectively removes finely like clay, shale and mineral matter which tend to retain significant amount of moisture. This mineral rich particle holds water in their structure and in their surface layer, so their removal reduces overall moisture content of the treated coal. On other hand recovery of hydrophobic coal particles flotation selectively recovers hydrophic coal particles while rejecting hydrophobic materials. Since hydrophobic particles repel water, they retain less moisture compared to hydrophilic minerals and oxidized coal. In reduction of surface area which allows them to absorb and hold more moisture .The removal of these fines through flotation results in product with lower surface area reducing the moisture content .fine slimes and high ash materials hold water more tightly, leading to higher moisture in row coal. During the froth flotation, some of the surface moisture evaporates due to exposure to air, leading to the slight decreasing in moisture content.

4.1.2 Volatile Matter

The volatile matter in raw coal is 23.46% and after flotation is 30.46% .This cause may be flotation tends to recover finer low density coal particles that are often associated with higher volatile matter. When the study area of coal is high ash forming minerals this can result dilute the volatile matter in coal. By reducing the ash content during flotation, the relative concentration of volatile matter increase. The increase in Volatile matter indicates successful beneficiation by flotation, as the process enhances the concentration of combustible organic material. When increasing of volatile matter is increasing after flotation, characteristics of low rank of coal. Because of the reduction in ash content, then the froth flotation is primarily used to remove minerals impurities (such as clay, quartz and pyrite) from coal. Since this minerals are non-combustible they do not contribute to volatile matter. When content decrease the remaining organic coal friction become more concentrated, leading to relative increase in volatile matter. During the flotation, finer and low density coal particle (which are often rich in volatile matter) have higher tendency to float. Then the higher inert and mineral matter rich frictions tend to sink. This result a clean coal products that is richer in macerals component like vitrinite which has the higher volatile matter content.

4.1.3. Ash content

The ash of coal vary from the 47.69 % to 41.15% before and after flotation can see in table three. This variation indicates that the flotation response is effective in the study area. High ash content can influence the combustion behavior of low grade fuel and combustion rate. The decrease in ash content reflects an improvement in coal quality. But the outcome of the result is high ash content this result the coal is low quality. Decreasing ash content improves the energy value (calorific value) of the coal and reduces waste. The attachment of air bubbles to the coal particles, the ash forming minerals (such as clay, quartz and pyrite) they may be found in then they are more hydrophilic and tend to stay in the water phase rather than attaching to the bubble .also the effective removal of mineral impurities since ash forming minerals are not hydrophobic, they remain in the slurry and are discharged as tailings. Some cleaned coal particle (with lower ash content) rise to the froth layer. When during flotation experiment the collector such as kerosene has enhance the hydrophobicity of coal particles and the frother like n- octanol help to stabilize the air bubbles ,ensuring that only hydrophobicity coal particles attach and rise to the froth layer .other also the higher density ash forming minerals cause to sink ,whereas lighter coal particles remain attached to bubbles and float .On other hand the effective process control optimizing parameter like reagent dosage, air flow rate and pulp density helps improve selectivity for further reducing ash content in coal product.

4.1.4 Fixed carbon content

Fixed carbon is the solid residue left after the volatile matter is driven off during the combustion. The fixed carbon content goes up as is a direct result of the flotation process removing ash-forming mineral matter and concentrating the carbon-rich organic material. This enhances the overall quality and energy content of the coal. The laboratorial result indicated the raw coal is 15.22% and treated coal is 23.13 .this study indicated the flotation is effective and removed the ash forming mineral contents. The increased in fixed carbon content improved the calorific value of the coal. The coal rank falls in lignite rank.

The increasing infixed carbon (FC) content in coal after flotation is mainly due to the removal of impurities ,particularly mineral matter (ash) and moisture .This removal of ash forming minerals flotation selectively separate low density mineral matter (such as clay, quartz and pyrite). This mineral matter does not contribute to fixed carbon content in the cleaned coal, and also in the reduction of moisture content during flotation, fine coal particles with hydrophobic properties attach to air bubbles and rise to the froth, while water loving impurities sink. This process reduce the moisture content further increasing volatile matter content contribute to slightly decreasing relative fixed carbon content. Volatile matter increase, but ash and moisture decrease significantly, fixed carbon content appear to increase in cleaned coal .The reason is the low rank of coal.

4.3 Calorific Value

The calorific value (CV**)** of coal is a measure of its energy content and determines its rank or grade. The experimental method of analysis of sample before and after flotation was carried out in geological survey of Ethiopia by the method of Adibatic calorie metter the result indicated 4002.21BTU/Ib and 6587.05BTU/Ib respectively. This coal falls in the lignite grade because its calorific value is between 2,000–4,000 cal/g before flotation**.** After the flotation the Calorific Value: 3,659.47 cal/g) coal remains in the lignite grade but is now on the higher end of the range, nearing sub-bituminous coal. While the flotation has improved the coal's energy potential, it remains unsuitable for high-energy applications compared to higher-rank coals like bituminous or anthracite. The reason of the reduction in ash content, so ash is inert material that does not support to the energy production .Also lower moisture content reduces the effective energy output because some energy is lost evaporating water during combustion .Flotation helps remove free moisture from coal thereby increasing dry calorific value. Volatile matter consists of hydrocarbon and gases that burns and contribute to heat generation .With higher volatile matter; the calorific value is increase further, as volatile component provided additional combustion energy for this reason calorific value is increases.

4.4 Sulfur Content

It is an important parameter in coal quality assessment because sulfur emissions during combustion contribute to environmental problems such as acid rain and air pollution. Reducing sulfur content is often a priority in coal cleaning and utilization. The experimental result of sulfur content of raw coal is o.78% and after treated is 0.73%. This result indicated that the flotation is effective because the reduced content of sulfur. Less than 1% is low sulfur content. In the removal of pyrite sulfur (inorganic sulfur) pyrite is high density hydrophilic mineral that does not readily attach to air bubbles during flotation .finally disseminated sulfur compound may be preferentially removed with the mineral matter further contributing to sulfur reduction .

4. 5 Coal Grade Determination

The classification based on ASTM(American Standard Testing Center),the classification based on fixed carbon value (typically dry mineral basis)(ASTM) D388 – 99 before treated 4002.21BTU/Ib of calorific value classified as lignite B and the after flotation the calorific value is increased into 6587.05BTU/Ib it is classified as lignite A. Generally the laboratorial experimental results high moisture content, high ash content ,high volatile matter content ,low fixed carbon content and low sulfur content. Finally the studied of coal type is lignite.

4.6 Floatation Results

The flotation pulp had a solid content maintained at 5 wt% for all tests, with tap water used as the medium(Ali et al., 2018). All conditioning and flotation tests were performed in triplicate, and the results represent the average values(Huang et al., 2018).

Table 4: Flotation result

Run	Collector dosage	Frother dosage	Particle size(µm)	Ash%	Grade%	Recovery%	Yield%
1	5	2	-250+125	25.5	74.5	4.43	2.74
2	10	2	-250+125	43	56.56	4.75	3.8
3	5	4	-250+125	45	55.25	3.72	3.15

4	10	4	-250+125	38.3	66.5	7.68	5.7
5	5	2	Under 75	39.5	60.46	12.96	9.89
6	10	2	Under 75	49.8	50.15	14.06	12.63
7	5	4	Under 75	50.9	49.01	28.73	26.3
8	10	4	Under 75	38	61.3	12.25	9.05

Figure 10: Flotation Experiment.

4.6.1 The effect of operating variables on flotation

The operating parameters of these tests significantly influence the efficiency of separation. They are the key parameters including particle size, collector dosage, and frother dosage.

4.6.1.1 The effect of particle size on recovery

It was observed that particles of varying sizes display distinct flotation behaviors under identical chemical conditions. The ideal particle size for coal flotation is typically less than 1 mm(Sokolovic & Miskovic, 2018). When particle size is the most important parameter in the flotation test .the density difference in of larger particle size quickly to settle down and the properties that exhibits to hydrophilic properties and the smaller particles are also exhibits in hydrophobic properties because of the density difference. Then seen in experimental results that the ash content of finer size have much higher than the larger size that may be the mineral mater of kaolinites is presents. Seen from table four and figure ten the particle size of -75μm recovery of concentrate is higher than -250 +125 particle size

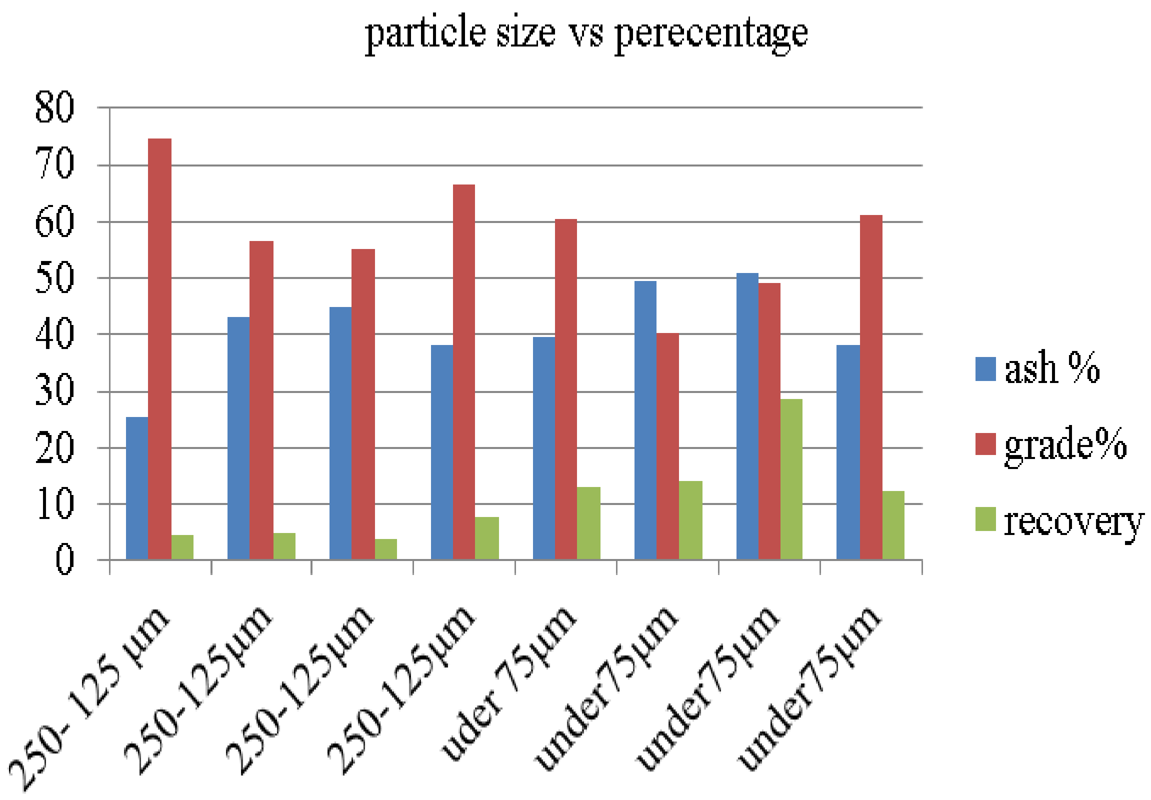


Figure 11: The effect of particle size on flotation response under ash, grade and recovery.

4.6.1.2 The effect of collector dosages on recovery

In table four indicates that collector dosage increase the recovery also increase but in experimental continual manner the equilibrium riches the concentration of collector we could to increments the result is no satisfactory because of the mineral physio- chemical properties behaviors. See in figure 11 higher collector consumptions produce the higher recovery and higher ash content, they may be the different mineral content in coal and the surface properties that minerals have their own different properties exist. The maximum value of flotation recovery was obtained at collector dosage of five milliliters.

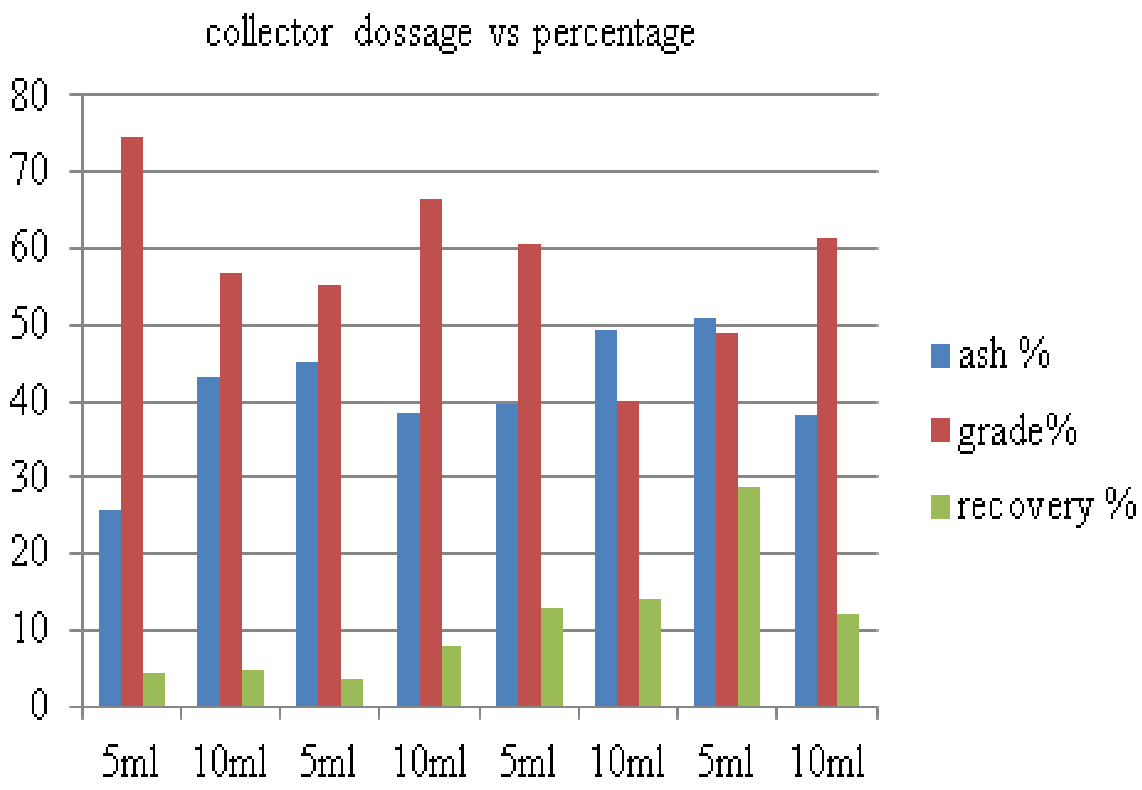


Figure12: The effect of collector dosage on flotation response under ash, grade and recovery

4.6.1.3 The effect of frother dosages on recovery

The effect of frother dosages that have directly effect on recovery because were seen in table four and see in figure 12 the frother concentration increase the recovery also increase when the equilibrium riches. The maximum value flotation recovery was obtained at frother dosage four milliliters. Excessive turbulence can negatively affect the froth stability, ultimately reducing the recovery rate. As a result, an increase in the gas flow rate will inevitably transfer a larger volume of water from the pulp phase to the froth phase(Paryad et al., 2017).

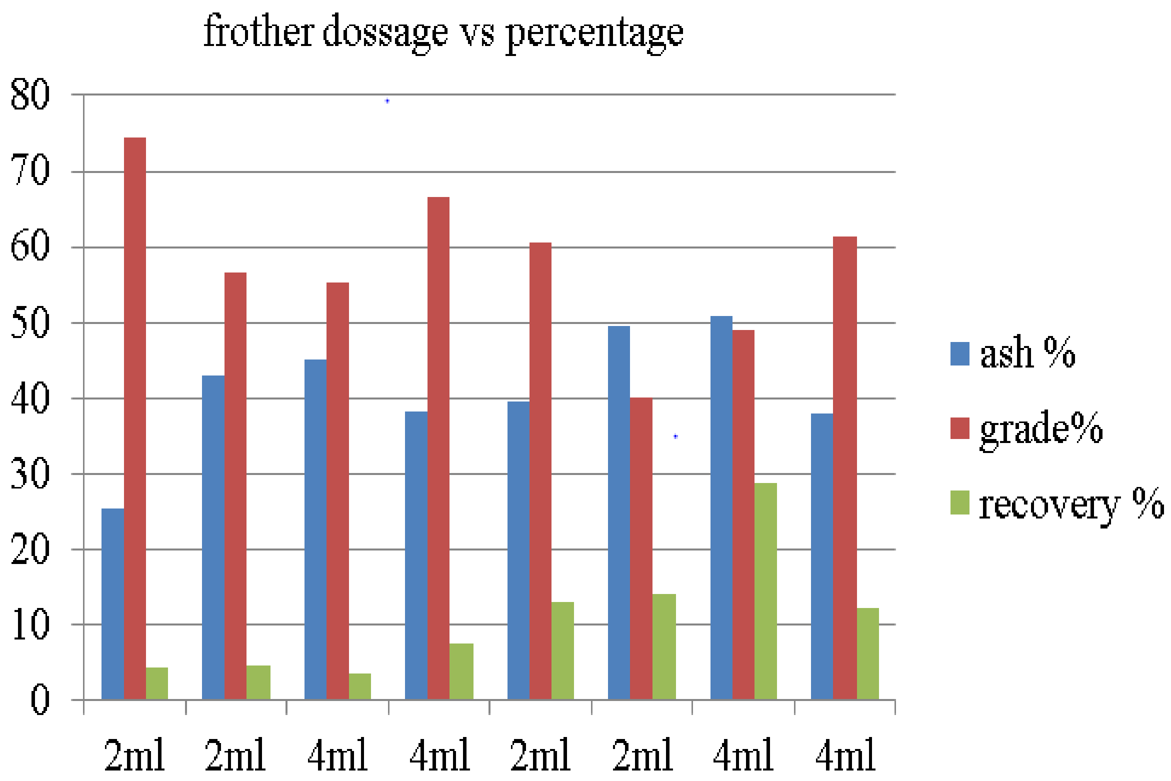


Figure 13: the effect of frother dosage on flotation response on ash, grade and

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Proximate analysis is critical in classifying coal rank and assessing its suitability utilized in various areas, such as energy generation and industrial processes. The experimental analysis of coal conducted before and after flotation reveals the following results: moisture content ranges between 5.27% and 13.64%, ash content varies from 41.15% to 47.69%, volatile matter ranges between 30.46% and 23.46%, fixed carbon content ranges from 23.13% to 15.13%, sulfur content is between 0.73% and 0.78%, and the calorific value ranges from 4002.21 BTU/lb to 6587.05 BTU/lb. The laboratory data shows that coal type is lignite A type before flotation and lignite B type after flotation according to ASTM 2000 standard. Based on the ASTM classification, the coal in the study area is identified as lignite. The calorific value serves as a crucial measure of coal quality, playing a significant role in ranking coal and evaluating its efficiency for energy production. Based on the sulfur content analysis, the coal from the study area is classified as low in sulfur. Coal characterization and flotation methods are essential for the beneficiation of coal in the study area, as they help enhance its economic value and environmental performance.

5.2 Recommendations

Based on the findings of the study, the researcher forwarded the following recommendations.

- ❖ Thus X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM**)** – identify mineralogical composition and morphological characteristics of coal for further information was used input for coal on study area is recommended.
- ❖ Those deep laboratorial investigations on surface chemistry analysis were used to evaluate hydrophilic and hydrophobicity of coal and gauge minerals was recommended on performance of flotation test.
- ❖ Thus the laboratory results of the proximate analysis which shown high amount of ash and low amount of fixed carbon but after flotation the calorific value is increasing because of reagent used collector like kerosene and frother N- octanol was used but, for effective separation collector like diesel and frother methyl isobutyl carbinol (MIBC) should be recommended on selection of reagents.

REFERENCES

Abebay, G., Chala, E. T., Jilo, N. Z., & Tiyasha, T. (2024). Improving the Stability of Mining Slopes in Tarcha Coal Mine, Southwestern Ethiopian Deposit Through Geometric Adjustments. *Advances in Civil Engineering*, *2024*(1), 8925294. https://doi.org/10.1155/2024/8925294

Ahmed, W. (2008). Fossil fuel energy resources of Ethiopia. *Bulletin of the Chemical Society of Ethiopia*, *22*(1). https://doi.org/10.4314/bcse.v22i1.61335

Ali, D., Hayat, M. B., Alagha, L., & Molatlhegi, O. K. (2018). An evaluation of machine learning and artificial intelligence models for predicting the flotation behavior of fine high-ash coal. *Advanced Powder Technology*, *29*(12), 3493–3506. https://doi.org/10.1016/j.apt.2018.09.032.

Han, O.-H., Kim, M.-K., Kim, B.-G., Subasinghe, N., & Park, C.-H. (2014). Fine coal beneficiation by column flotation. *Fuel Processing Technology*, *126*, 49–59. https://doi.org/10.1016/j.fuproc.2014.04.014

Huang, G., Xu, H., Ma, L., & Wu, L. (2018). Improving Coal Flotation by Classified Conditioning. *International Journal of Coal Preparation and Utilization*, *38*(7), 361–373. https://doi.org/10.1080/19392699.2016.1267639

Jorjani, E., Mesroghli, Sh., & Chelgani, S. C. (2008). Prediction of operational parameters effect on coal flotation using artificial neural network. *Journal of University of Science and Technology Beijing, Mineral, Metallurgy, Material*, *15*(5), 528–533. https://doi.org/10.1016/S1005-8850(08)60099-7

Jovanovski, G., Boev, B., & Makreski, P. (2023). Chemistry and geology of coal: Nature, composition, coking, gasification, liquefaction, production of chemicals, formation, peatification, coalification, coal types, and ranks. *ChemTexts*, *9*(1), 2. https://doi.org/10.1007/s40828-022-00177-y

Kebede, J., & Cheepurupalli, N. R. (2019). An overview of Ethiopia’s coal potential as a source of energy and future mining opportunities. *JOURNAL OF CRITICAL REVIEWS*, *6*(07).

Li, Z., Ward, C. R., & Gurba, L. W. (2010). Occurrence of non-mineral inorganic elements in macerals of low-rank coals. *International Journal of Coal Geology*, *81*(4), 242–250. https://doi.org/10.1016/j.coal.2009.02.004

Liew, M., Xiao, M., & Liu, S. (2021). Characterization of physical and mineralogical properties of anthracite and bituminous coal tailings. *International Journal of Coal Preparation and Utilization*, *41*(9), 645–660. https://doi.org/10.1080/19392699.2018.1503175

Mathu, K., & Chinomona, R. (2013). South African Coal Mining Industry: Socio-Economic Attributes. *Mediterranean Journal of Social Sciences*. https://doi.org/10.5901/mjss.2013.v4n14p347

Meshram, P., Purohit, B. K., Sinha, M. K., Sahu, S. K., & Pandey, B. D. (2015). Demineralization of low grade coal – A review. *Renewable and Sustainable Energy Reviews*, *41*, 745–761. https://doi.org/10.1016/j.rser.2014.08.072

Oni, S. O., Olugbenga, E. A., & Chidimma, G. N. (2017). CHARACTERIZATION OF ASH CONTENT, COKING TENDENCIES AND EVALUA- TION OF PHYSICOCHEMICAL PROPERTIES OF OKOBO COALS. *Petroleum and Coal*.

Osborne, D. G., & Gupta, S. K. (2013). Industrial uses of coal. In *The Coal Handbook: Towards Cleaner Production* (pp. 3–30). Elsevier. https://doi.org/10.1533/9780857097309.1.3

Pandit, Y. P., Badhe, Y. P., Sharma, B. K., Tambe, S. S., & Kulkarni, B. D. (2011). Classification of Indian power coals using K-means clustering and Self Organizing Map neural network. *Fuel*, *90*(1), 339–347. https://doi.org/10.1016/j.fuel.2010.09.012

Paryad, H., Khoshdast, H., & Shojaei, V. (2017). Effects of operating parameters on time-dependent ash entrainment behaviour of a sample coal flotation. *Journal of Mining and Environment, Online First*. https://doi.org/10.22044/jme.2017.857

Polat, M., Polat, H., & Chander, S. (2003). Physical and chemical interactions in coal flotation. *International Journal of Mineral Processing*, *72*(1–4), 199–213. https://doi.org/10.1016/S0301-7516(03)00099-1

Pudasainee, D., Kurian, V., & Gupta, R. (2020). Coal. In *Future Energy* (pp. 21–48). Elsevier. https://doi.org/10.1016/B978-0-08-102886-5.00002-5

Sahu, D., Chaurasia, R. C., & Suresh, N. (2019). Mineralogical characterization and washability of Indian coal from Jamadoba. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *41*(5), 517–526. https://doi.org/10.1080/15567036.2018.1520336

Scott, A. C. (2002). Coal petrology and the origin of coal macerals: A way ahead? *International Journal of Coal Geology*, *50*(1–4), 119–134. https://doi.org/10.1016/S0166-5162(02)00116-7

Sokolovic, J., & Miskovic, S. (2018). The effect of particle size on coal flotation kinetics: A review [PDF]. *Physicochemical Problems of Mineral Processing; ISSN 2084-4735*. https://doi.org/10.5277/PPMP18155

Tesfu, S., & Dawit Habte, G. (2021). Identification, characterization and evaluation of honeybee floras in Kafa, Sheka and Benchi Maji Zones of Southern Nations Nationalities and Peoples Region (SNNPR), Ethiopia. *International Journal of Agricultural Science and Food Technology*, 310–326. https://doi.org/10.17352/2455-815X.000125

Wakuma, B., & Assaba, B. (2017). Physicochemical Characterization of Coal and its alternative use as a Source of Energy (in case of Yayo Coal Mining Industry). *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *11*(05), 44–50. https://doi.org/10.9790/2402-1105034450

Walle, H., Zewde, S., & Heldal, T. (n.d.). *Building stone of central and southern Ethiopia: Deposits and resource potential*.

Wang, Y., Xing, Y., Gui, X., Cao, Y., & Xu, X. (2018). The Characterization of Flotation Selectivity of Different Size Coal Fractions. *International Journal of Coal Preparation and Utilization*, *38*(7), 337–354. https://doi.org/10.1080/19392699.2016.1256875

Ward, C. R. (2002). Analysis and significance of mineral matter in coal seams. *International Journal of Coal Geology*, *50*(1–4), 135–168. https://doi.org/10.1016/S0166-5162(02)00117-9

Widodo, S., Sufriadin, Thamrin, M., Wahyufirmansyah, & Jafar, N. (2020). Mineralogy and quality of Banti Coal, Baraka District, Enrekang Regency, South Sulawesi Province, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *473*(1), 012112. https://doi.org/10.1088/1755-1315/473/1/012112

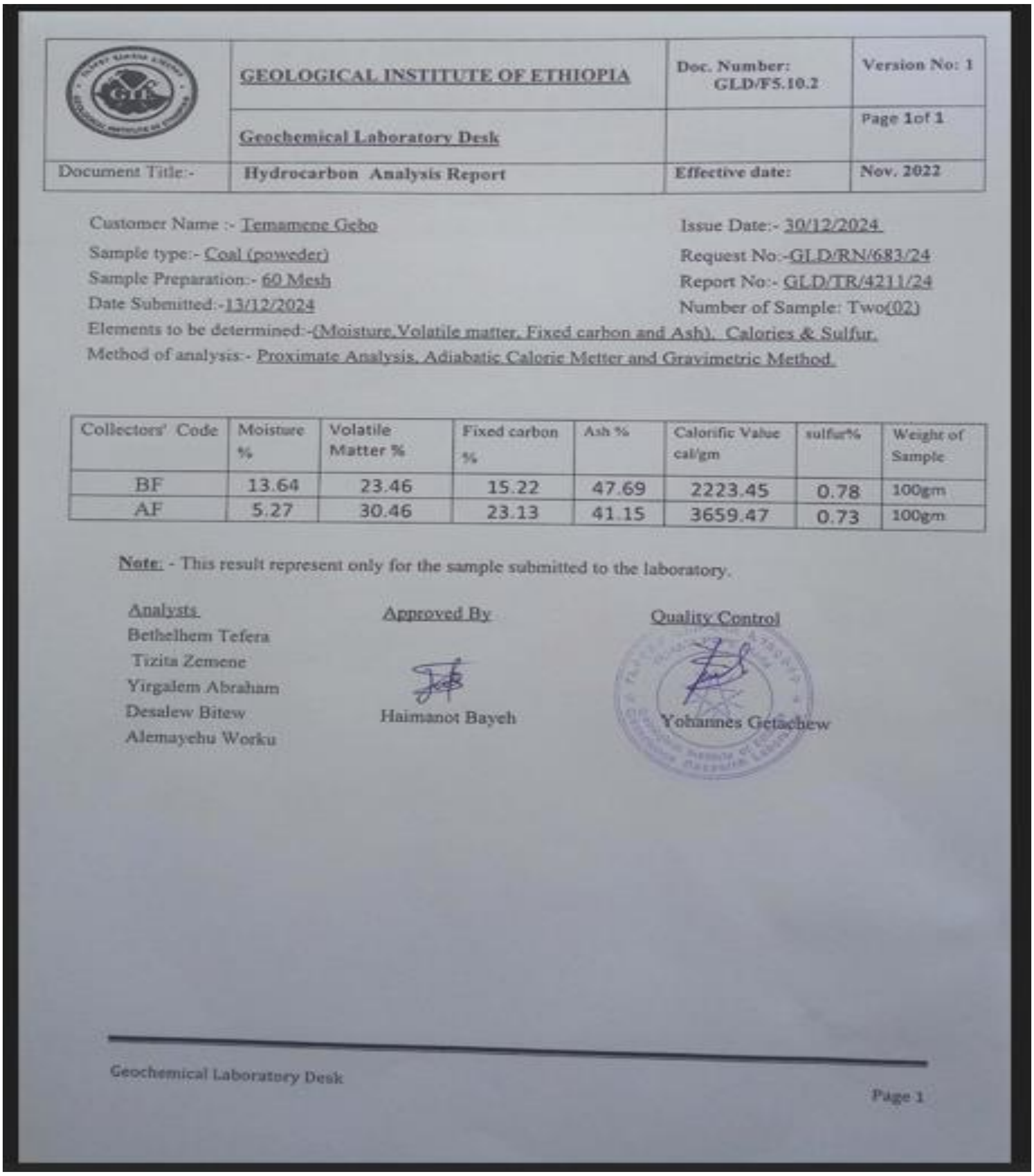
Xie, K.-C. (2015a). *Structure and Reactivity of Coal: A Survey of Selected Chinese Coals*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-47337-5

Xie, K.-C. (2015b). *Structure and Reactivity of Coal: A Survey of Selected Chinese Coals*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-47337-5

Yilmaz, S. (2021). Coal grindability before and after coal cleaning and a new approach considering differentiation of proximate analysis data and total sulfur. *International Journal of Coal Preparation and Utilization*, *41*(4), 233–247. https://doi.org/10.1080/19392699.2019.1605989

APPENDIX

Supplementary Fig. Coal sample before and after flotation those are value of laboratory analysis result by Geological survey of Ethiopia.



	GEOLOGICAL INSTITUTE OF ETHIOPIA	Doc. Number: GLD/F5.10.2	Version No: 1
	Geochemical Laboratory Desk		Page 1of 1
Document Title:-	Hydrocarbon Analysis Report	Effective date:	Nov. 2022

Customer Name :- Temamene Gebo
Issue Date:- 30/12/2024
Sample type:- Coal (poweder)
Request No:-GLD/RN/683/24
Sample Preparation:- 60 Mesh
Report No:- GLD/TR/4211/24
Date Submitted:-13/12/2024
Number of Sample: Two(02)
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
BF	13.64	23.46	15.22	47.69	2223.45	0.78	100gm
AF	5.27	30.46	23.13	41.15	3659.47	0.73	100gm

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

Analysts
Bethelhem Tefera
Tizita Zemene
Yirgalem Abraham
Desalew Bitew
Alemayehu Worku

Approved By
Haimanot Bayeh

Quality Control
Yohannes Getachew

Geochemical Laboratory Desk
Page 1