A Comprehensive Investigation of the Quality of Coal at Selected Mines in Jharkhand

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Abstract- Among these sources of energy is coal that has accounted to an estimated 67 percent of the overall supply of energy in the country. India has one of the greatest coal reserves in the world. The Indian coal has low returns of calorific value and very elevated levels of ash. However, with the present levels of 0.8 million tons of average of daily output of coal in the country, the reserves are estimated to last over 100 years. In India energy derived out of coal is nearly twice energy derived out of oil, compared with the world, where energy derived out of coal is nearly 30 percent lower than energy derived out of oil. It is the rock that is composed of the remaining of plant remains that have been decomposed and therefore consist mainly of an element known as carbon and this is what we call coal. Combusting coal brings about heat energy which could be used in engines such as steam engines or to produce electricity using turbines. Coal burning contributes to nearly 67 per cent of the electricity produced in INDIA. Coal quality is called coal quality and is attributed to the properties and characteristics of coal that influence behaviors and use. The quantities and distribution and varieties of the many and varied elements that are found in coal that is proposed to be burned are a few of the other coal-quality aspects of future use of coal. These quality aspects about the Indian coal deposits may lead eventually to our better use of this life-sustaining energy source with a cheaper and more effective cost, and with the least amount of unnecessary environmental pollution. The objective and vision of this project work is that it narrows its scope on quality of various Indian Coals and also finds out which coal can be used in which industry. Analysis of coal also helps in determining of coal rank alongside as implicit property. Additionally, this information will form the fundamental consideration of arriving at future related issues e.g.: coal trading and its usages. Coal Properties and tests the coals were sampled as an example of 05 mines out of the Jharkhand coal mines on the basis of channel sampling process. Different coal properties were studied and were put to test that gives us some information about quality of the coals. The various properties tested include the following - Plastic properties, Physical & Chemical properties, Thermal properties of peculiar coal.

1.INTRODUCTION

1.1 COAL DEFINITION

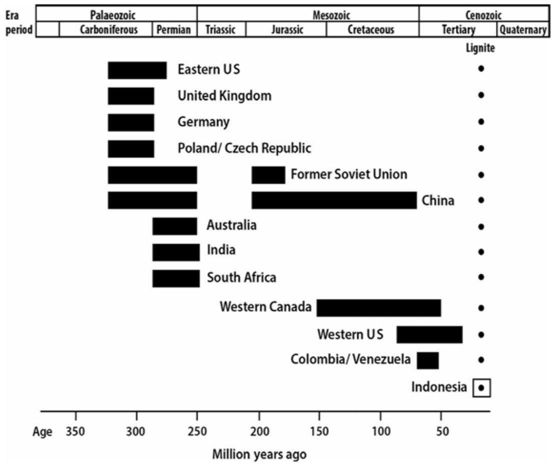
In 1993, Van Krevelen produced a comprehensive description of coal: Coal is a multiphase colloidal system, a rock, a sediment, a conglomerate, a biological fossil, a solid-state physics conundrum and a delight to be studied physically and chemically. Simply put, coal is a kind of sedimentary rock that can be burned and has both inorganic and organic constituents. The bulk of organic composition of coal comprises carbon, hydrogen and oxygen and there is also reduced fringe of sulfur and nitrogen in coal. Coal also comprises of many ash producing compositions spread inorganically in the coal. The inorganic parts of coal can range up or down in proportion to fractional percentage points to parts-per-billion.

1.2 ORIGIN OF COAL

Seams are coal deposits, which were constructed as a result of aggregation of vegetation that has been subjected to chemical and physical alteration. These are some of the transformations such as degrading in vegetation, being covered by the sediments, compaction and the conversion of plant debris to the present-day rocks. Coals in the world vary depending on the type of plant matter deposited (coal type), the amount of metamorphosis or coalification (coal rank), and the extent of impurities carried by the coal (coal grade). With regard to the buildup of vegetation that produces coal seams, there exist two basic hypotheses (Moore, 1922). First theory or instead most accepted one is that the coal formed in situ, or the location where the vegetation was found. This is as it provides the references to the source of a majority of the coals. Such type of a deposit is referred to as autochthonous. The majority of coal energy sources originated as fertile peat swamps where there was almost stationary water and the accumulations of vegetation wastes. Through several generations, vegetation tended to grow and this vegetation matter was amassed on the surface of the marsh and was transformed into peat because of the actions of microbes. A coal seam developed when the marshes flooded and were engulfed in sedimentary deposits later. The process was repeated millions of times to form additional coal seams. This has been repeated over and over again hundreds of thousands of years leading to the formation of more coal seams. These depositional and build up cycles were then followed by tectonic (geological) and diagenetic (biological) processes.

Lastly, the different grades of coal now seen were all created due to the effect of the amount of heat applied, period of time, and pressure. The possibility to explain how most coals were formed because of the autochthonous process does not say that this tendency can be easily extended to certain deposits. The water with the vegitable matter deposited along the course to compose some of the coals. This theory (i.e. allochthonous origin) shows that these plant bits were carried to the sea floor or a lake bottom and were crushed together to result in the formation of solid rock. Since the Upper Carboniferous age (which occurred between 350 and 270 million years ago), major coal deposits have developed in virtually all geological ages; the timeline of major coal deposit formation being depicted in Fig. 1.1 (Walker, 2000). Fig. 1.1 indicates comparative ages of the biggest coal resources of the world. The great diversity of the meteorological and botanical conditions which prevailed during the chief ages of coal-formation, as well as the subsequent geophysical action, explains to a great extent, the great diversity of the diverse coals. The coal formations were most pronounced in the carboniferous period. Africa, South America and North America collided in a block and turned into one land mass (Pangea) and a mountain building zone what is now southern and northern Europe.

Fig: -1.1 Comparative Geological Ages of World Hard Coal and Lignite Deposits.



Walker was a proper diet (Berkowitz, 1979; Walker, 2000). The developed coal basins are depicted in Fig. 1.2; some of overlapping the eras of the continental reconstruction. During the Lower Carboniferous period (or Mississippian period), the Tethys Sea began to retreat slowly to its present-day boundaries of the modern Mediterranean Sea and coal began to amass in Pennsylvania and Virginia, New Brunswick and Nova Scotia, Scotland, Northumberland (Britain) and Maine, Brittany and Basse-Loire (France) (Berkowitz, 1979).

That principal Carboniferous coal strata were formed in the Northern Hemisphere, whilst the southern half of the continent of Pangaea (Gondwana) was at the South Pole. This continent shifted toward the north as the Permian period approached and it changed to a subarctic climatic zone in place of a cold temperate one. Apparent coal formation also occurred in the Permian age in Australia, South Africa, India and South America (Walker, 2000; Berkowitz, 1979). The Jurassic Period saw the rift between Africa and North America. Coal deposits in Australia and China today formed during the Triassic and Jurassic periods. By the Cretaceous epoch, Africa was already pulling apart with South America and the Pacific Philippine Plate began to break off with the Asian continental plate. Collision and subduction in the North and South American cordillera led to major deformation, as the Indian plate approached Asia (Walker, 2000). The last great part of formation of coal, covering the period between the Cretaceous and Tertiary, grew out of these movements. Coals of various geological ages may also be different to each other because they are formed differently (Walker, 2000; Berkowitz, 1979). Northern

Hemisphere (Laurasian) Carboniferous coals are also over-represented by the maceral group of vitrinite that is common to rapid sinking deposition (explained later in the chapter). The high rates of various seams usually characterize such deposits. Much of the Southern hemisphere (Gondwanan) Permian coals occur on more solid shelf locations, and in a few cases, the cores became very high-density layers that shifted into carbonaceous shale. The number of vitrinite is varying. In addition, the Gondwanan coals also tend to possess greater mineral wastes than Laurasian coal in forms of fine scattered clay and quartz grains that are hard to free during the beneficiation procedure. In general, the Laurasian coals were richer in sulfur than the Gondwana coals. This seems to correlate with the observation that the Gondwana coals are commonly layered with freshwater-derived deposits and that the Laurasian coals have more marine roof deposits.

1.3 COALIFICATION

Geochemical conversion of vegetation to coal is usually termed Coalification: Peat- Lignite -Sub bituminous - Bituminous - Anthracite. More complex forms have developed and are described in later in the chapter; this is a basic division. Tatsch (1980) resolve that the process of coalification consists of three processes namely: viz., microbiological destruction of cellulose of the initial plant material; transformation of lignin of the plants to humic materials; and recondensation of humic material to bigger coal molecules. These are all based on the type of decaying vegetation, the phase of the decay process at which it has been, the location in which it is laid and also on the crustal movement of the earth (Van Krevelen, 1993).

The most significant factors which determine the process of coalification are the physical forces which interact with the reserves. These coal variations have been produced because of change in chemical composition of the flora that has formed the source of coal initially (Van Krevelen, 1993; Schobert, 1987). The specific situations when the plants were decomposers matters since the floras of the different geologic periods were chemically and biologically distinct. Other features that are important in the production of the coal are the depth, the swamp temperature, acidity and natural water flow (Van Krevelen, 1993; Mitchell, 1997). Geochemistry phase of the coalification process is the most important since pressure and temperature are exerted during the millions of years.

The physical results manifested to be a decrease in porosity as the degree of gasification and vitrification increases but the issue that has aroused some debates is which of the two factors plays a larger role in enhancing the chemical and physical changes: the high pressures of the heavy strata of massive over-burdening or the time-temperature conditions (Elliott, 1981)The coal forming center or the core of the plant life, undergoes a series of successive reactions in the process of coalification. Highly reactive components (e.g. hemicelluloses, some extractives) can be oxidized or volatilized because of heat and pressure. This material is able to leak out of the fuel complex.

The lignins, which keep the material which constitutes the biomass in place are known as the glues and are retained in the fuel structure and their single constituent elements possess aromatic built structure. Lignins and other unmodified biological materials squeeze out under pressure and heat to become peat then the multiple kinds of coal. The coal products of the condensation processes either contain 2-6 fused aromatic rings depending on the coal rank. Other coalification processes are modifications in the functional groups appended to the fused aromatic moieties, or coal backbones themselves. The higher up in the ranks, the fewer the functional groups. These include functional groups of methoxy (O_ (COOH_3)) that is common in large quantities in lignites and some subbituminous coal.

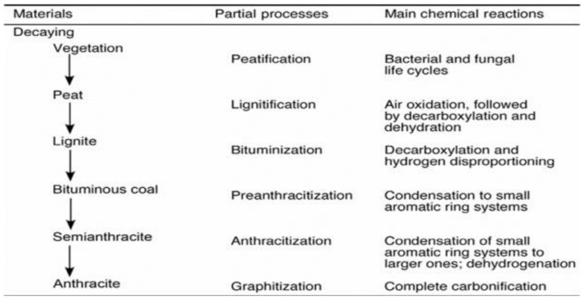
These functional groups do not exist in bituminous coals and concentration declines with rank. In analyzing the chemical modifications of coal with rank increase (i.e., increasing coalification), it is important to consider the characteristics of oxygen, as determined by Van Krevelen and Schuyer (1957). Table 1.1 indicates that the concentration of overall oxygen, together with highly receptive functional groups oxygen (O-COOH, O (COOH 3), and O OH), is greater in the lower-rank coals. Oxygen concentration in the coal reductions with increment rank (reflected in the increase of carbon concentration) and very high percent in the most reactive functionality falls to approximately zero. Chemically: as rank increases, the moisture and volatile matter (which can include carbon dioxide and methane) content are reduced, percent carbon slowly increases, percent oxygen slowly reduces, and eventually at an anthracitic stage, percent hydrogen greatly reduces (Schobert, 1987; Elliott, 1981).

Approximations have also been given by Berkowitz (1979), Schobert (1987), Singer (1981), Miller et al. (2003) among others with the following ranges: 50 percent carbon in herbaceous plants and wood, 60 percent in peat, 70 percent in lignite, 75 percent in subbituminous coal, 80 to 90 percent in bituminous coal, and >90 percent in anthracite (dry basis; mineral matter-free). Such shift in carbon concentration is referred to as Carbonification. The process of coalification/carbonization is illustrated in figure 1.3 and among the prominent chemical reactions taking place in the process of coalification/carbonization, a list of some is presented there (Van Krevelen, 1993).

Table 1.1 Oxygen Content by functional group

Carbon Content (%)	Oxygen Content by Functional Group (Wt.%)				
	O_COOH	O_(COOH_3)	O_OH	O_(C=0)	O_NR
65.5	8.0	1.1	7.2	1.9	9.6
70.5	5.1	0.4	7.8	1.1	8.2
75.5	0.6	0.3	7.5	1.4	6.4
81.5	0.3	0.0	6.1	0.5	4.2
85.5	0.05	0.0	5.6	0.5	1.75
87.5	0.0	0.0	3.2	0.6	1.3
88.6	0.0	0.0	1.9	0.25	0.85
90.3	0.0	0.0	0.5	0.2	2.2

Fig 1.3 The coalification process.



Materials	Partial processes	Main chemical reactions
Decaying Vegetation		
↓	Peatification	Bacterial and fungal life cycles
Peat		
↓	Lignitification	Air oxidation, followed by decarboxylation and dehydration
Lignite		
↓	Bituminization	Decarboxylation and hydrogen disproportioning
Bituminous coal		
↓	Preanthracitization	Condensation to small aromatic ring systems
Semianthracite		
↓	Anthracitization	Condensation of small aromatic ring systems to larger ones; dehydrogenation
Anthracite	Graphitization	Complete carbonification

1.4 THE COAL CLASSIFICATION

More than 185 years ago, the work of trying to classify coal was commenced by the necessity of making some effort at bringing something approaching order out of the confusion which characterized the identification of various coals. There were two systems of classification systems invented, one was to thrive scientific research and the other one was to serve coal consumers and manufacturers. The trade and market issues connected with coals, their use, the technical features, and their adaptation to the specific end-use are correlated with commerce systems of classification, in contrast to scientific systems of classification that are focused on genesis and structure and basic characteristics of coals. We will in this case discuss the latter classification schemes. Elaborate explanations of scientific categories can be found elsewhere (Berkowitz, 1979; Van Krevelen, 1993).

1.4.1 Essential Coal Analysis

The principals in classification schemes are provided with the simple coal analyses, which are discussed later on by rank, type and grade and also by COAL classification schemes. No information on coal structure can be obtained through these analyses but they are useful in calculating the behaviours and are applied in marketing of coal. Classification of coal is done in three analyses; one analysis is a calorific determination and the other two are of chemical analysis. The proximate and the final measurements are a part of the chemical measures. Proximate analysis: The percentage moisture, volatile and ash matter i.e. the inorganic matter left after the entire combustible matter is burned out and the quantity of fixed carbon of the coal.

Coal composition is generally expressed as % carbon, hydrogen, nitrogen, sulfur and oxygen. Oxygen is difficult to directly quantify, and as a result is commonly calculated by difference, i.e. as 100 % less the sum of the quantified other elements. Such a method however, gathers up any errors in the other measurements. Calorific value is the other critical parameter: this indicates the energy that will be created when the material burns. As ash and moisture are not combustible, results can be reported on varying bases indicating the conditions of testing of the sample, e.g., as-received, air-dried, dry ash-free (DAF) or dry mineral-matter-free (DMMF) to best reflect the energy potential of coal. fig. 1.4 exhibits the most frequently occurring bases of the multiple classification systems (Ward, 1984). The descriptions of the most frequently took bases are the following (Van Krevelen, 1993):

As received-quantity of moisture is mentioned as percentage of coal. It is sometimes also called as-fired because no more coal remains and it is widely utilised in combustion engineer calculations and operational procedures monitoring.

Dry basis (db): The data are exhibited in coal percentages with moisture eliminated.

The data are presented in the form of percentages of the coal remaining after removing the moisture and ash on the dry, ash-free (DAF) basis.

Dry, mineral-matter-free (DMMF) basis: the data represents a measure of the pure organic part of the coal and a coal is assumed to be free of moisture and mineral matter. Moist, ash-free (MAF) basis: this is a condition that the coal is assumed to be still damp and contains no mineral matter in the form of the ash.

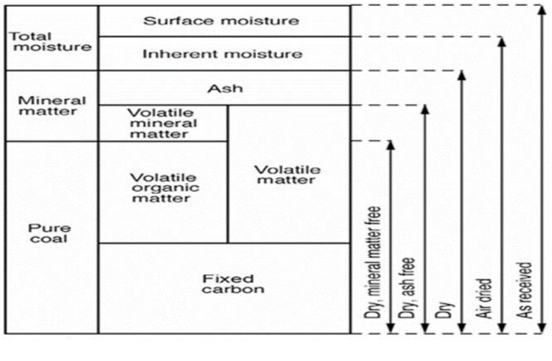
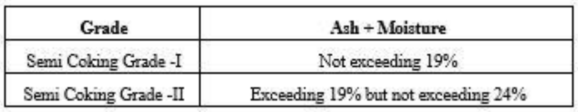


Fig 1.4 Relationship of different analytical bases to coal components.

1.5 THE COAL GRADES

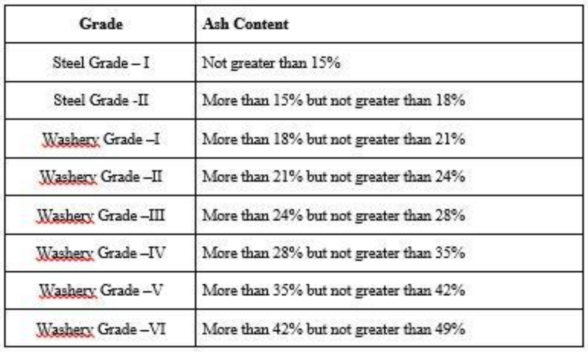
The quality of coal is indicated by coal grades, which are distinguished by the quantity of mineral stuff contained in the coal. There are also grades of coal with regards to the content of sulphur in it, the ash fusion temperatures (this is a measure of the behavior of the ash in the high temperatures) and the amount of the trace element. Grade is important to coal users although currently no formal systems of classifying coal grades exist. The mineral particles may occur as discrete coal partings or may be in a finely dispersed form. Originally present in the plant, some of these trace elements and inorganic remains can be traced back to the first plant, but most of them are deposited into the peat bog during coalification through the action of water or winds, or by the movement of solutions through fissures, cracks, and the caves (Mackowsky, 1968). Coal mineralogy may affect the properties of metallurgical coke, coal combustion and conversion (i.e. production of liquid fuels or chemicals) and the capability to recover minerals during coal preparation and cleaning. Grades of Semi-coking and Weakly Coking Coal



Grade	Ash + Moisture
Semi Coking Grade -I	Not exceeding 19%
Semi Coking Grade -II	Exceeding 19% but not exceeding 24%

Table1.2 -Grades of Coking Coal

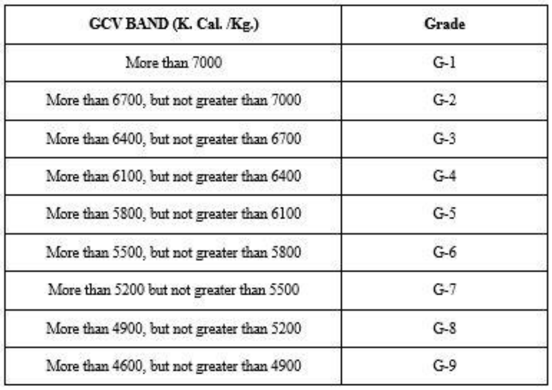
Grades of Coking Coal



Grade	Ash Content
Steel Grade – I	Not greater than 15%
Steel Grade -II	More than 15% but not greater than 18%
Washery Grade –I	More than 18% but not greater than 21%
Washery Grade –II	More than 21% but not greater than 24%
Washery Grade –III	More than 24% but not greater than 28%
Washery Grade –IV	More than 28% but not greater than 35%
Washery Grade –V	More than 35% but not greater than 42%
Washery Grade –VI	More than 42% but not greater than 49%

Table 1.3 –Grades of Semi-coking and weakly coking coal

Grades of Non-coking Coal



GCV BAND (K. Cal. /Kg.)	Grade
More than 7000	G-1
More than 6700, but not greater than 7000	G-2
More than 6400, but not greater than 6700	G-3
More than 6100, but not greater than 6400	G-4
More than 5800, but not greater than 6100	G-5
More than 5500, but not greater than 5800	G-6
More than 5200 but not greater than 5500	G-7
More than 4900, but not greater than 5200	G-8
More than 4600, but not greater than 4900	G-9

Table 1.4- Grades of Non-coking Coal

1.6 QUALITY OF COAL IS ESSENTIAL

The nature of coal influences the quality of their properties including calorific value, ash content, volatile matter, moisture content, sulfur content, and elemental composition. These aspects exert an impact on the emissions, the design of the combustion system and the combustion efficiency. To illustrate, an ash may have high sulfur contents resulting in an abundance of sulfur dioxide emissions that greatly pollutes the environment as gases and a high amount of water may cause slagging and boiler fouling.

1.7 TECHNIQUES FOR ANALYZING COAL

Coal analysis can be seen according to two large categories:

Proximate Analysis: This is the process that measures the wetness content, volatile matters, fixed carbon, and ash of the coal. It is also commonly used in routine assays, and that provides a quick read on how good the coal is and potential combustion behavior.

Ultimate Analysis: The composition of simple elements in the coal such as carbon, hydrogen, nitrogen, sulfur and oxygen in quantitative terms are revealed by an Ultimate Analysis. It gives details of the chemical make-up of the coal and how it burns up.

1.8 IMPORTANCE TO THE INDUSTRY

In most industries, the correct evaluation of coal quality is indispensable.

Power Generation: Guarantees effective burning and adherence to environmental regulations.

Cement and Steel Production: Assesses coal's viability as a fuel and reducing agent.

Emissions are measured and cleaner technology is developed with the help of environmental monitoring.

1.9 The project's objective

To determine the physical and chemical characteristics of coal in samples such as moisture, ash, volatile matter, and fixed carbon.

To come up with calorific value of coal obtained in chosen mines in order to evaluate the energy efficiency and commercial usefulness of the coal.

To examine the content of impurities and tracers, e.g., sulfur and heavy metals, that affect interplay in the environment and combustion trends.

To match the quality traits of coal of various mines all over in Jharkhand state to determine spatial differences and the influential geology.

To categorize the coal according to country and international standards and determine the applicability of the coal in several industrial processes.

2.LITERATURE REVIEW

2.1 Previous Studies

Berkowitz (1979) and Elliott (1981) divied that coal consists of macerals, separate minerals, inorganic elements bound to organic matter by molecular interactions and water and gases trapped in submicroscopic pores. These materials are composed principally of plant tissues which have been sunk by burial, decayed by microorganisms, compacted by pressure, and converted into other forms of matter by geological processes.

Berkowitz (1979) and Elliott (1981) further highlighted that macerals, the organic component of coal, can be in many instances linked to particular parts of the initial plant debris out of which the coal was formed. The gross simplification of this and its presentation in coal is shown in Fig. 2.1. This figure also demonstrates the contribution of inorganic components dissolved as ions and mineral grains, which make source materials more complex.

Taylor et al. (1998) and Bustin et al. (1983) came up with a system of classification that takes account of the natural heterogeneity of the organic matter in coal. This petrographic classification was initially used to correlate coal seams and investigate coal diagenesis and metamorphism though it is now the method by which coal which can be used industrially can be tested.

SuArez-Ruiz and Crelling (2008) and Miller and Tillman (2005) have indicated that coal petrography plays a crucial role in industrial estimation due to the capacity of coal petrography which provides information in regard to the coal constituent and the combustion properties. Macerals fall into three large groups based on their optical properties, chemistry and structure: vitrinite, liptinite (exinite) and inertinite.

The groupings have a number of different maceral types and subtypes, which are detailed in the work by Berkowitz (1979), Elliott (1981), Taylor et al. (1998), and Bustin et al. (1983).

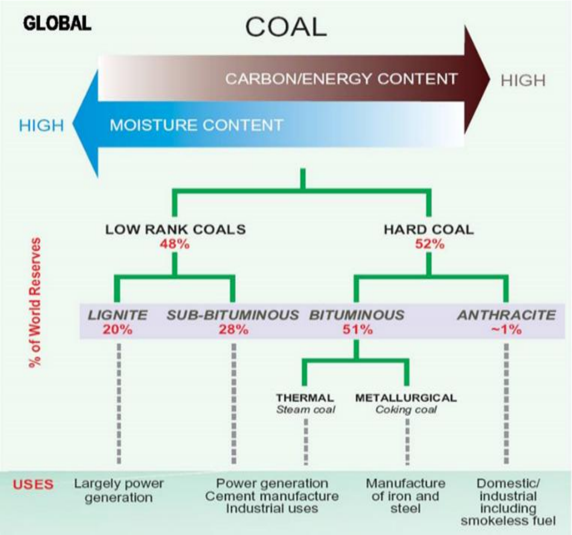


Fig-2.1 Classification of Coals Groups by Rank and Indices of Organic Maturity

Coal, as an example of a fossil fuel is one of the most prevalently utilized in the world today, particularly in industrial purposes and electricity generation. To best utilize them and reduce their negative effects on nature, the characteristics of various coal samples are to be known. Different scholars have been studying the samples of coal in the various geographical areas to get their physical, chemical and thermal traits. The important methods of coal analysis are proximate analysis, ultimate analysis, determination of calorific value and analysis of sulfur content.

Proximate analysis is used to identify the moisture content, volatile matter content, ash content and that of fixed carbon in coal. In considering a thermal use, coal containing a greater percentage of fixed carbon, as well as low ash, is most desirable (Singh et al., 2016). Globally, some Indian coals have been found to vary significantly in terms of ash (1545%), moisture (312%), depending on their geological origin. Correspondingly, Zhou et al. (2018) examined the comparison of different types of coals in China and concluded that bituminous coals have greater volatility and more limited ash contents and are therefore more appropriate in coking. These differences in proximate values are not unusual as coal forms in many and varied geologic environments. Further explaining this heterogeneity and its aspects added to coal usage, Ghosh et al. (2021) carried out a proximate analysis of coal samples of the Jharia coalfield.

Based on proximate analysis Jharia coal has a medium to high (5-8%) target moisture, high ash (20-35%), high volatile matter (23-28%) and a fixed carbon of about 35-45%. Ghosh et al. (2021) summarised that despite the poor efficiency of Jharia coal in producing thermal power because of its high ash and volatile matter content, it possesses a relatively high carbon content, which qualifies it as coking coal. Singh and Kumar (2020) contrasted coal of Ramgarh and Bokaro Regions in a comparative study. According to them, Ramgarh coal because of shallower seams is more moist (~10%), less ash (~22%) and has superior fixed carbon (~50%). It was stressed in the study that the coal in the deeper seams is likely to be of more useful energy content, thus creating more economic and environmental advantages in its use as energy material.

Proximate analysis of North Karanpura sub-bituminous coal done by Roy et al. (2022) indicates moisture in the range of 6210%, volatile matter of 2832%, ash content 2530%, and fixed carbon 3038%. The paper provided a significance of coal washing and coal blending to achieve higher thermal efficiency and minimize emissions. In a more recent study, more sophisticated techniques were also used by

Chakraborty et al. (2023), who conducted a proximate analysis accompanied by thermogravimetric analysis (TGA) in order to learn more about the burning properties of the Indian coals. The multi-location study conducted by them found that there is an increase in the fixed carbon content and a decrease in the amount of ash of washed coal. Further, moisture and volatile matter variations strongly depended on the burial depth and the geological ages of coal seams which is another evidence of the necessity of the depositional history in defining coal quality.

Although the authors employed high-grade methods of analysis, Chakraborty et al. (2023) stressed that proximate analysis is essential in assessing coal quality. The ultimate analysis provides the information on the fundamental behavior of combustion as it provides information on the elemental composition of coal that is carbon (C), hydrogen (H), nitrogen (N), sulfur (S) and oxygen (O). As stated by Tiwari and Mahapatra (2020), carbon content is directly related to the calorific value of coal, with a higher concentration of sulfur and nitrogen posing high chances of environmental pollution through combustion. As the example, South African coals are characterized by 60 70 wt. % of carbon and fairly low sulfur content (1 2 wt. %), meaning that they can be used in a wide range of energy processes. On the same note, despite the lower carbon in the Indonesian low-rank coals, the presence of lowest levels of sulfur makes them more desirable since they will have cleaner burning.

The gross or net calorific rate (GCV/NCV) indicate the energy produced by burning coal. GCV of anthracite (GCV>30 MJ/kg) and other high-rank coals are higher whereas that of other low-rank coals especially lignite (GCV~15 MJ/kg) are lower. Bhatt and Kumar (2017) assert that coal samples with high moisture and ash can increase their calorific values, which influences their volatility burning properties. Comparative research finds that Australian black coals possess some of the highest GCVs on earth, and thus constitute premium export fuels. Ash and mineral materials influence the boiler performance and slagging behavior. Some studies conducted by Patel et al. (2019) have identified that high ash coals often pose difficulties to the Indian thermal power plants, which requires them to be regularly taken care of. Mineral constituents in coal ash are described by the application of various methods, like X-ray diffraction (XRD) and float-sink characterization.

3.COAL PROPERTIES

3.1 Chemical Characteristics

There are four primary or quality categories or grades of coal these being anthracite, graphite, bituminous coal, or black coal, and lignite, or brown coal. The physical properties of a variety of coal is determined by moisture concentration, the degree of the presence of volatile (especially aliphatic or aromatic hydrocarbons) and carbon content. All coal that is mined is carried out in wet form which is a critical property of coal. The adventitious moisture is the ground water and other exterior moisture and both are easily evaporated. The water that is stored between the coal itself is inherent moisture that is quantified in a measurable quantity. The four possibilities of the moisture occurring in the coal include:

Surface Moisture: Surface water the water that is on the top of coal or macerals is called surface moisture.

Hydroscopic Moisture: The water retained by capillarity in the microfractures of coal.

Decomposition Moisture: The water contained in the decomposed organic matter of coal is referred to as decomposition moisture.

Mineral Moisture: Mineral moisture refers to water which has been included as a component of the crystal structure of hydrous silicates (including clays).

Volatile Matter: The volatile component of coal, or that which volatilizes at a high temperature in air absence, consists of the components of coal--exclusive of moisture. This is normally a mixture of aromatic hydrocarbons, short and long-chain hydrocarbons with a little percentage of sulphur. A regulation driven measure is the volatile matter in coal. The coal volatiles are more likely to increase its reactivity and flammability.

Ash: Ash content in coal refers to the amount of the non-inflammable coal after coal is burnt. It adopts the substantial minerals substance that is common after carbon burning is eliminated and contains, carbon, oxygen, Sulphur and water (and clays). When the coal has been burned out and the amount of ash expressed as a percentage of the original mass, the analysis is much simplified. Mineral matter falls into two categories: (1) Significant (2) Unnecessary Inherent is of inorganic parts of vegetable matter, but is present in smaller amounts. The quantity added to compounds during their conversion is extraneous. They are connected to inner structures and they are very many. They are hard to eliminate.

Connection between mineral matter and ash is as follows:

M.M = 1.08Ash + 0.555

For Indian coals:

M.M = 1.1Ash

Coal containing high ash is:

Rigid and Tougher.

Small calorific value.

Will produce slag.

Sinter formation.

Coal Containing High Ash is:

Rigid and Tougher: High ash content often makes coal physically denser and tougher, which can affect its grindability and handling.

Small Calorific Value: Since ash is a non-combustible residue, a high ash percentage reduces the proportion of combustible material in the coal, leading to lower heat energy output during combustion.

Will Produce Slag: The inorganic components in high-ash coal can melt at furnace temperatures and form slag a molten or partially fused mass—which can damage furnace linings and reduce efficiency.

Sinter Formation: Sinter are hard lumps formed when ash particles fuse together at high temperatures. High ash content increases the likelihood of clinker formation, which can obstruct fuel beds in boilers and cause operational issues.

Fixed Carbon: Fixed carbon is the carbon content of a coal sample left after the volatile constituents are removed. This does not compare to the eventual carbon level of the coal since some of it is lost in the process of forming the hydrocarbon with the volatiles. Fixed carbon helps in the determination of the quantity of coke that will be produced by a specific sample of coal. Fixed carbon is the difference between the mass of the volatiles observed in the volatility test above and the initial mass of the coal sample. The fore-mentioned parameters are whenever established using proximate analysis. According to ultimate analysis, the elemental components of coal include carbon, hydrogen, nitrogen, sulfur, and oxygen.

3.2 PHYSICAL ASPECTS

Specific Gravity: Coal's specific gravity is influenced by the amount and kind of mineral content and organic mass. The more ash coals, the greater the specific gravity of the same kind of coal. The real specific gravity of bituminous coals ranges between 1.27 and 1.45. With many of the Indian coals, the following formula is applicable:

Where,

S = Specific gravity

A = Percentage of Ash

k = a constant, value is 1.25

An average specific gravity of 2.25 is supposed in the above formula of the mineral matter of coal.

Densities: Coal's density varies with rank and measurement method, in part because of its finely structured void volume. Coal density is therefore a term that means more than one thing, and a distinction should be made between bulk densities, which depend on the mean size of coal particles (or lumps), the size distribution, and on their packing density. These influences impact on coal handling, transportation and storage. The ratios of the weights to volumes of undisturbed coal in their respective seams, the in-place densities, are important elements in estimating coal reserves. The apparent specific densities which depend on the molar volume of the liquid and are dimensioned by the displacement of the liquid. The absolute densities, the supposedly true densities of biological coal at all of its metamorphic levels.

Angle of Repose: The coal pile's angle with the horizontal is crucial for both its storage and its movement through feed hoppers and conveyors. Depending on factors like surface roughness and moisture content, it could vary by two to three degrees. Generally speaking, the angle of repose increases with coal size. This implies that a heap of a specific height may hold a larger quantity of coal of larger sizes. Specific Heat: As coal's volatile matter content rises and its C/H ratio falls, its specific heat also rises. Moisture and specific heat have a linear connection.

Porosity, Heat of Wetting, Surface Area: Few characteristics have a more direct and immediate impact on coal behavior than pore space. This is always so widespread and so finely structured, even in anthracites, that coal is given the properties of a solid colloid and resembles a solid sponge. Heat of wetting measures the surface area of coal. The Porosity, Surface area and Heat of Wetting changes with rank of coal in the same manner as moisture changes with rank.

3.3 THERMAL PROPERTIES

Powdered coal sample is heated in an atmosphere free of air and the occluded gases consisting of methane, ethane, nitrogen, carbon dioxide are lost below 100 ^{0}C. A temperature of 100 to 150 ^{0}C releases moisture. bituminous coals require 200-300 ^{0}C to start decomposition, but active decomposition of coals starts at 300-375 ^{0}C. Pyrogenic water is produced during the primary devolatilization (300-550 ^{0}C) and particular tar and gasses as well as gasses (mostly hydrogen) formed during the Knock over devolatilization (700 ^{0}C). When coal is heated, it is shown that decomposition of coal takes place but it has an added effect of an increase in the carbon content of the residue. Upon coking of caking coals, the residue melts into a plastic stage of 300- 350 ^{0}C to 500-550 ^{0}C.

The plastic mass behaves like a fluid in the sense that the fluidity does not jump all the way, and attains a high value at some point and then becomes relatively lower, to the zero. On increasing the heat on coke, significant changes are experienced up to approximately 2000 o C during which graphite type substances are derived. This is referred to as graphitization and is used in the production of graphite electrode and the other articles. Non-caking coals cannot be graphitized. Porosity is decreased as coal is heated and reached its minimum stage in the plastic state. The level of porosity of coke is 40 or more percent and the level considerably increases after solidification once again. This aspect allows the coke to burn smoothly within portable spaces. Because thermally decomposed plastic is formed by the formation of the volatile material, the carbonaceous residue first contracts and de-porosities before expanding, swelling, and becoming more porous.

3.4 PLASTIC PROPERTIES

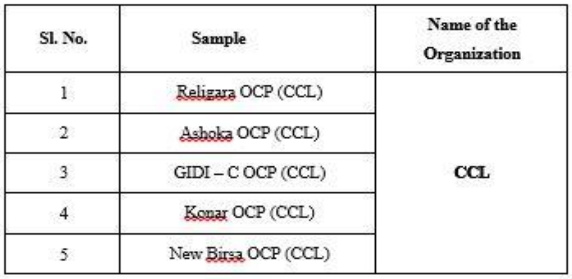
In the process of heating coal passes through an intermediate phase known as the plastic state (caking). Where a particular coal does not pass into a plastic stage it is called a sintered mass (non-coking). Tests of plasticity of coal are by caking index test, free swelling test, GKLT and Plastometer.

4.METHODOLOGY

4.1 SAMPLE COLLECTION

The consequences of any sample, even the simplest, will include a great number of possible errors. Such mistakes can be caused by the structural nature of the ore, its distribution, or texture. Moreover, measurement errors might occur due to the type of sampling method used, the quality of application, or the sampler equipment. To be absolutely accurate, a set of samples cannot simply represent the coal mass; a set of isolated specimens only. Instead, the term sample is most often used to refer to material that has been literally separated out of its source to conduct laboratory tests. One essential guide in the correct selections of sampling position and spacing is derived out of professional experience, which comes with having sampled thousands of mines. The experience enables one to make informed changes to suit the situation of individual mines, even after initial samples have been taken. This mastery has resulted in standard procedures with time focused on reducing the subjective influence in sample selection. Of these, application of different types of drilling technology is typical, though one common method is channel sampling which is the traditional and generally shared approach.

4.2 SELECTED COAL SAMPLES



Sl. No.	Sample	Name of the Organization
1	Religara OCP (CCL)	CCL
2	Ashoka OCP (CCL)	
3	GIDI – C OCP (CCL)	
4	Konar OCP (CCL)	
5	New Birsa OCP (CCL)	

Table 4.1 Samples of Coal that were selected and used in this work

Coal samples were collected in this manner, channel sampling. The following is a protocol of coal channel samples.

Some portion of a fresh coal surface was chosen to sample.

Do not use previously rock dusted coal faces or those diamonds that are oxidized.

Sampling a fresh face, in a deep mine, is perhaps possible shortly after bolting the roof and preparing the succeeding cut.

The sample in surface mining can be taken on a fresh face once loading stage is over during mining. Simple looking face that was a bed mark was chosen. The coal can be hand-picked back into a proper surface at the top and at the bottom.

The surface was covered with the 3–4-meter of the nylon reinforced sturdy vinyl tarpaulin. Vertically drawn two lines crayoned on the coal surface, separated by 10 cm. Sample units to be used were chosen.

The layers to be excluded ought to have already been established in case the exclusionary entity was to be established. It started digging along the bottom of a coal bed using a pick and the middle coal along the lines was chipped down to about 8 cm. This was then replayed right to the channel buttom.

The channel back was squared by hand as to ensure there is an equal volume cut on the channel cut. Samples of small channels may be cut along two sides of the 10 cm wide block surface of the breakdown by employing gas powered masonry cutoff saws.

In the equivalent process with deep mines the hand augur drilled a set of holes in the two sides of the 10-cm-wide block along the column up through the block and down to the bottom to reveal a column which could be sampled.

The total sample was then separated into drums or in polyethylene-line canvas bags. The representative splitting can be traced later in the laboratory.

The container we used on the outside was labeled, each container was closed individually as well, and the interior bag contained a correctly labeled sample tag as well.

All the samples were gathered as per the above-mentioned approach. We have five samples of coal collected in four coalfields.

4.4 ANALYSIS IN PROXIMITY

4.4.1 Calculating the Moisture Content (M)

A weight of approximate 1gm of new coal powder (-212m) air dried coal was weighed in a silicon crucible and transferred to an electronic hot air oven set at a temperature of 108+2C. The specimen of coal in the piece of crucible was removed by the after one and a half hours had elapsed by the help of a tongue-rider and left in a desiccator to cool off pipe after a lapse of about fifteen minutes to go through the process of being weighed. The percentage weight loss appears as a moisture. It is calculated as given below:

An air-dried and finely powdered (-212) of coal (ca 1g) was placed into a height alongside a VM crucible in an muffle furnace preheated at 925 C. On this was added the lid of the crucible. To which the crucible was taken, air cooled and placed in a desiccator and again weighed after a precise seven minutes heating. The estimate is calculated as followed:

4.4.3 Calculating the Amount Of (Ash)

To a clean, empty silicon crucible, 1g of a fine-ground (-212m) air-dried sample of coal was added. Before this, the crucibles were preheated i.e. at 800 o C and this took about an hour in order to remove any foreign substance. The crucible and sample were inserted into a muffle furnace, which was heated to 450 C, and allowed to get burnt in it approximately 30 minutes. Then, the sample was heated up about an hour to a temperature of 850 nC that is the temperature of the furnace. The calculation is done as follows:

Fig. 4.3 Muffle Furnace

4.4.4 Determination of Fixed Carbon (C)

The fixed carbon content of coal is given by the following formulae

%C = 100 – (%M+%VM+% Ash)

A measure of the grindability of coal would refer to its physical properties e.g. hardness, tenacity and fracture plus the ability to be crushed to powder, to be used as pulverized fuel. With the natural gradient, brown to lignite and anthracites, there exists a constant correlation in the grindability and the ranking of coal. Coals that are easily ground possess 14-30 percent of volatile stuff. Coals that are liable to higher volume are more difficult to grind. But the grindability is affected by mineral and petrographic components. The moisture content of coal and therefore, the humidity of the environment where the test is carried out influences the hard groove index.

5.EXPERIMENTAL PROCEDURE

5.1 ANALYSIS IN PROXIMITY

A silica crucible that is weighed is packed with approximately 1 g of well crushed, air-dried coals sample that has been reduced into a particle size of 212microns (BSS) is weighed and placed into in an electric hot air oven and the temperature is held constant at 1100C.

Once the coal sample is placed in crucible, the coal sample is left in the oven to dry up; after one and a half hours, with tongues; the crucible is then taken out of the oven and left to cool in the desiccation which takes a period of about fifteen minutes. Then it was weighed, Weights of moisture lost are reported as percentages. The calculation can be made as follows.

Where,

X = weight of empty crucible, in grams (gm)

Y = weight of crucible + coal sample before heating, in grams (gm)

Z = weight of crucible + coal sample after heating, in grams (gm)

Y -X = weight of coal sample, in grams

Y- Z = weight of moisture, in grams (gm)

The crucible's empty weight is measured.

After weighing one gram of the appropriate coal sample in a crucible, it is placed in a muffle furnace and heated to 450 degrees Celsius for thirty minutes, then to 850 degrees Celsius for sixty minutes.

Following that period, the crucible is removed, put in a desiccator, and weighed.

Where

X= weight of empty crucible in grams (gm)

Y= weight of coal sample + crucible in grams (gm) Before heating

Z= weight of coal sample + crucible in grams (gm) After heating

5.2 HARDGROVE GRINDABILITY INDEX

A 1-kilogram sample of coal was then crushed in such a way that the sample could pass through a 4.75milimeter sieve. The last sample remained screened using two sieves; the upper sieve of 1.18 mm and lower sieve of +600m. Sift the material in two minutes till when all of them are able to pass through a 1.18 mm sieve. Once the 1.18mm*600um size-coal was mixed completely, it was removed using a sample divider as 120g of the sample. The 120g sample was added into the ball mill 8 iron ball balls (25.4mm +/- 0.003mm) were added into the ball mill. The ball mill was sealed and it was allowed to turn to approximately

60 turns after which we stopped the machine. Associated with it came the removal of any powdered material that may have fallen on the machine using a brush and there followed a transfer of the sample that remained in the ball mill to a sieve of 75 m and shaking after approximately ten minutes. The sample that passed through the sieve was then placed on a balance in five minutes.

Calculation- Hard groove grindability of coal is obtained as follows:

HGI = 13 + 6.93 W

W = weight of the test sample passing through 75µ sieve after grinding.

6.RESULT ANALYSIS

6.1 ANALYSIS OF RESULTS

The proximate analysis was conducted on coal samples collected at five opencast projects (OCPs) of Central Coalfields Limited (CCL) such as Religara, Ashoka, Gidi C, Konar, and New Birsa. Some of the parameters that are investigated include Moisture (%), Ash (%), Volatile Matter (%), and Fixed Carbon (%). In the results it was found that there are great differences between collieries as regards to the quality of coal.

Moreover, the ability of coal samples to be pulverized also differed within each other, the Hardgrove Grindability Index (HGI) was between 57.28 and 76.09. An elevated HGI value indicates easier grinding properties in general.

Sample No.	Name Of Colliery	Moisture (%)	Ash (%)	Volatile Matter (%)	Fixed Carbon (%)
01	RELIGARA OCP (CCL)	5.08	29.12	22.31	43.49
02		5.30	28.68	25.32	40.70
03		5.68	27.47	21.33	45.52
04		6.11	26.00	22.13	45.76
05		6.19	26.35	21.87	45.59

Table 6.1: Proximate Analysis of RELIGARA OCP (CCL) Coal Samples

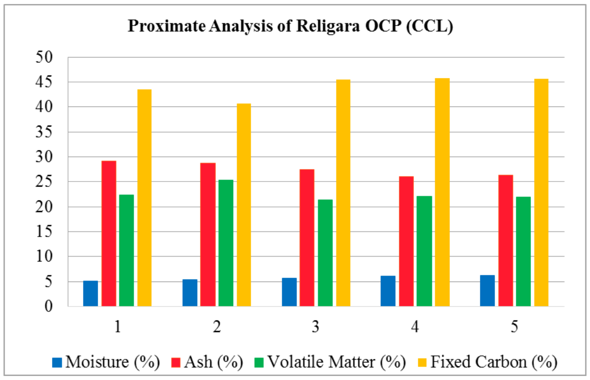


Fig: - 6.1 Proximate Analysis of RELIGARA OCP (CCL) Coal Samples

Sample No	Name Of Colliery	Moisture (%)	Ash (%)	Volatile Matter (%)	Fixed Carbon (%)
01	ASHOKA OCP (CCL)	7.38	41.66	21.76	29.20
02		9.19	34.48	22.31	34.02
03		9.18	30.90	22.77	37.15
04		7.04	35.22	22.84	34.90
05		7.98	29.15	26.92	35.95

Table 6.2: Proximate Analysis of ASHOKA OCP (CCL) Coal Sample

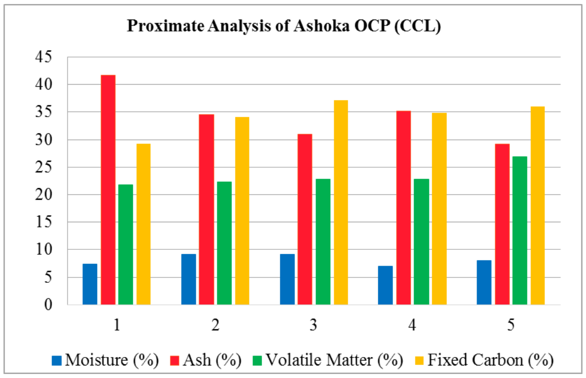


Fig: - 6.2 Proximate Analysis of ASHOKA OCP (CCL) Coal Sample

Sample No.	Name Of Colliery	Moisture (%)	Ash (%)	Volatile Matter (%)	Fixed Carbon (%)
01	GIDI C OCP (CCL)	3.00	44.47	19.69	32.84
02		3.16	46.27	20.60	29.97
03		4.07	38.82	19.59	37.52
04		5.02	35.32	20.35	39.31
05		4.58	33.14	23.64	38.64

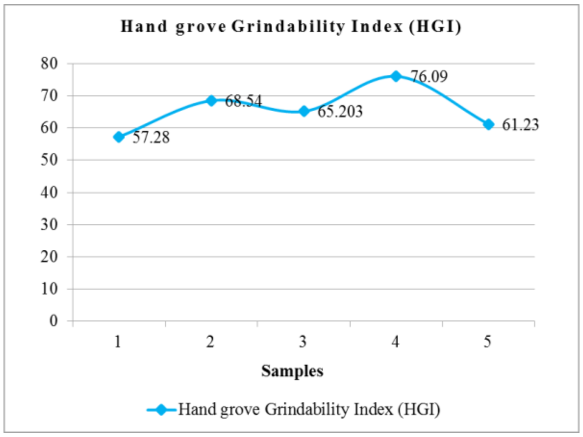


Fig: - 6.5: Proximate Analysis of NEW BIRSA OCP (CCL) Coal Sample

The grindability index of all the coal samples that were collected for the study.

Table 6.6: HGI of the Coal Samples Curve

Fig: - 6.6: HGI of the Coal Samples Curve

7.DISCUSSION AND CONCLUSION

7.1 DISCUSSION

The quality of some Indian coals was tested with the help of a number of experiments that were carried out in the process of the project activity. The experiments which have been performed are the hardgrove grindability index (HGI) and proximate analysis. The plastic characters could not be established since the samples collected failed to coke. This also was not done because there was no space to conduct the experiments required in the final analysis. of the five samples of each of the mines. which were performed according to Indian Standard practice. Table 6.1 shows the percentage moisture (M), volatile matter (VM) and ash content (A) of each sample. Table 6.1 depicts the fact that a sample with the least moisture content is no. 1 (5.08 percent) and the highest moisture content sample is no. 05 (6.19 percent). Generally the moisture content of the wine was found to be within 5.08 per cent and 6.19 per cent. Based on this, we can conclude that sample number five will need a longer period to heat up and hence, have a low calorific value. Moreover, when comparing with other coals the sample number five will be utilized more when it comes to a specific heating application. It was also discovered that sample 3 contained the least quantity of volatile matter (21.33%), the quantity of volatile matter in sample no.2 and 1 were the greatest quantity of the volatile matter (25.32 and 22.31 respectively).

It has already been mentioned that in the use of coals in combustion processes, high volatile-matter coals are so reactive that they readily ignite. The more volatile material in coal the lower the calorific value of the coal. Very convenient samples no. 2 and 1 could be used in combustion application, but it might need greater volume of the furnace to do that. Due to their potential to generate larger amounts of tar and gases, these coals could be potentially used in liquefaction and gasification processes. The ash value of Sample No. 1 is 29.12 and 26.00 and that of Sample No. 5 is 52 per cent. Most of the samples will be problematic as they contain more than 25 percent ash in their composition, which may be problematic during combustion. They could lead to clinkers settling in the furnaces thereby making the reactions difficult. burning such samples will contaminate the environment a lot. It is thus, crucial that they clean these samples of coal before they can be used in the industries. Plot of Sample Numbers vs Proximate Analysis Constituents The fixed carbon content has varied in direct proportion to the calorific value, tending toward 40.70% (sample no. 2) and 45.59% (sample no. 5).

Table 6.1 demonstrates that 5 of the samples have a fixed carbon level which is less than 50%, implying that the calorific value will probably be low. These samples may be applicable in combustion activities in small organizations and thermal power plants. The grindiability index of coal gives a clue on the strength of coal. It is an index applied in measuring the ease or hardness in grinding a coal. The index values of grindability of the samples varied between 68.54 (sample no. 2) and 76.09 (sample nos. 04). Table 6.6 indicates that there are few numbers of samples whose grinding is easy compared to the number which grinds very difficult. An index can be used to determine the size of the crushers and grinders that should be used in plants involved in the preparation of coal.

7.2 CONCLUSION

1. OCP Religara (CCL)

A thorough analysis of the coal composition from Religara OCP (CCL) has been conducted based on the data, highlighting differences in moisture, ash content, volatile matter, and fixed carbon among samples. These results offer crucial information about the quality, effectiveness, and suitability of the coal for industrial uses. Important Points to Note:

Moisture Content: A moderate amount of natural moisture in the coal is indicated by the moisture percentage, which ranges from 5.08% to 6.19%. Effective drying techniques may improve usability because a higher moisture percentage can reduce energy yield and combustion efficiency.

Ash Content: The ash concentration exhibits a small decrease trend among samples, ranging from 29.12% to 26.00%. Lower ash concentration is preferred for cleaner combustion and less slag formation since ash in coal has a direct impact on furnace efficiency and environmental pollutants.

Volatile Matter: Volatile matter, which ranges from 21.33% to 25.32%, is essential to ignition characteristics. Improved combustibility is usually indicated by a higher volatile matter concentration, which makes some samples better suited for applications that need easy igniting.

Fixed Carbon: The fixed carbon content varies, reaching a high of 45.76%. For industrial thermal applications, higher fixed carbon often results in improved energy output and longer burn times.

2. Ashoka OCP (CCL):

Moisture Content: The moisture percentage, which ranges from 7.04% to 9.19%, is extremely high when compared to other types of coal. Excessive moisture lowers calorific value, lowers combustion efficiency, and increases transportation expenses. In order to maximize usability, drying treatments could be necessary.

Ash Content: Some samples had a noticeably high ash percentage, ranging from 41.66% to 29.15%, which suggests a decreased energy efficiency. High ash levels impair furnace efficiency; therefore, efficient ash handling methods are necessary to alleviate operational problems.

Volatile Matter: Influences ignition properties and ranges from 21.76% to 26.92%. As demonstrated in Sample 05 (26.92%), higher volatile matter increases combustibility, making this coal better suited for uses where simpler ignition is desired.

Fixed Carbon: ranges from 29.20% to 37.15%, with lower-ash samples often showing a rising tendency. Applications needing continuous heat output benefit from higher fixed carbon content since it increases thermal efficiency and burn time.

3. GIDI C OCP (CCL)

Moisture Content: In comparison to other coal sources, the moisture percentage is very low, ranging from 3.00% to 5.02%. Because lower moisture improves energy efficiency, these samples can be burned more easily and require less drying.

Ash Content: Some samples, particularly Sample 02 (46.27%), have noticeably high ash levels, which range from 46.27% to 33.14%. For industrial applications, improved ash control techniques are necessary because excessive ash reduces the energy production.

Volatile Matter: The percentage of volatile matter that affects ignition and combustibility ranges from 19.59% to 23.64%. Sample 05 has the most volatile matter (23.64%), which indicates improved ignition characteristics and is therefore preferred for simpler combustion.

Fixed Carbon: The range of values is 29.97% to 39.31%; more fixed carbon is typically associated with higher energy output. Sample 04 has the most promising properties for high-efficiency fuel applications, with 39.31% fixed carbon.

4. Konar OCP (CCL)

Moisture Content: The moisture content is abnormally low, ranging from 1.03% to 1.40 percent. This improves combustion efficiency and lessens the need for pre-use drying.

Ash Content: This indicates considerable impurity levels, ranging from 29.12% to 34.32%. Samples with less ash, such as Sample 03 (29.12%), are favored because they produce more energy and have fewer problems with furnace slagging.

Volatile Matter: The ignition qualities are directly impacted by values ranging from 16.49% to 20.23%. Sample 04 is better suited for slow combustion applications since it contains the least amount of volatile matter (16.49%). On the other hand, Sample 03 (20.23%) has comparatively more volatile stuff, which makes igniting simpler.

Fixed Carbon: Sample 04 has the highest value (50.54%), with this parameter ranging from 45.36% to 50.54%. These samples are very effective for thermal applications because higher fixed carbon results in better energy output and longer combustion times.

5. New Birsa OCP (CCL)

Moisture Content: Moderate moisture levels are indicated by the moisture levels, which range from 3.50 to 5.60 percent. Overall, the data indicate a tolerable moisture content for processing and use, even though higher moisture (5.60% in Sample 01) can decrease combustion efficiency.

Ash Content: Sample 03 has the greatest ash content (23.20%), which ranges from 17.90% to 23.20%. Samples with less ash (such as Sample 01, which has 17.90%) are better for fuel economy and emissions.

Volatile Matter: The readings, which range from 28.56% to 29.07%, show consistent ignition and combustibility characteristics across samples. These samples are perfect for applications needing quick combustion since their higher volatile matter facilitates easier ignition.

Fixed Carbon: Sample 02 exhibits the highest fixed carbon value (47.49%), with values ranging from 43.77% to 47.49%. These samples are perfect for power generation and industrial furnaces because of their high fixed carbon content, which guarantees longer combustion and improved thermal efficiency.

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