ASSESSMENT OF COAL QUALITY OF SOME INDIAN COALS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY
IN
MINING ENGINEERING

BY
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NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA - 769008
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National Institute of Technology, Rourkela

CERTIFICATE

This is to certify that the thesis entitled **"Assessment of Coal Quality of Some Indian Coals "** submitted by **Sri Anudhyan Mishra** in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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Anudhyan Mishra
Date:

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ABSTRACT

Coal is one of the primary sources of energy, accounting for about 67% of the total energy consumption in the country. India has some of the largest reserves of coal in the world. Indian coal has high ash content and low calorific value. However, with the present rate of around 0.8 million tons average daily coal extraction in the country, the reserves are likely to last over a 100 years. The energy derived from coal in India is about twice that of energy derived from oil, as against the world, where energy derived from coal is about 30% lower than energy derived from oil.

Introduction

The rock that we refer to as coal is derived principally from decomposed organic matter (plants) consisting primarily of the element carbon. When coal is burned, it produces energy in the form of heat, which is used to power machines such as steam engines or to drive turbines that produce electricity. Almost 67% of the electricity produced in INDIA is provided by coal combustion.

"Coal quality" is the term used to refer to the properties and characteristics of coal that influence its behavior and use. Among the coal-quality characteristics that will be important for future coal use are the concentrations, distribution, and forms of the many elements contained in the coal that we intend to burn. Knowledge of these quality characteristics in Indian coal deposits may allow us to use this essential energy resource more efficiently and effectively and with less undesirable environmental impact.

The objective of this project work is to analyze the quality of various Indian Coals and find out which coal is suited best for which kind of industry. Also coal analysis helps in determining the rank of the coal along with its intrinsic characteristics**.** Furthermore, these data will be used as the fundamental consideration for future concerns, for instance: coal trading and its utilizations.

Coal Properties and their Tests

Coall samples were collected from 15 different mines of Talcher Coalfield, Talabira Coalfield, Ib Valley Coalfield and Chirimiri Coalfield following channel sampling procedure. Various coal properties were studied and their tests were carried out, which gives us some information about the quality of coals.

The various properties that were studied are as follows:

- Plastic properties
- Physical & Chemical properties.
- Special property of coal.

The tests which were carried out are:

- Proximate analysis
- Determination of hardgrove grindability index
- Determination of calorific value of coal by Bomb calorimeter.
- Washability studies.

The results of proximate analysis, hardgrove grindability index and calorific value have been presented in table 1.

Table 1: Coal Sample Results

Sample No.	Proximate Analysis				HGI	Gross Calorific Value (kcal)	Net Calorific Value (kcal)
	M (%)	VM(%)	A(%)	FC(%)			
1	4.5	25.04	34.56	24.6	68.54	3896	3596
2	6.65	28.25	26.92	34.92	59.22	4558	4258
3	5.24	25.01	33	37.1	65.203	4796	4496
4	5.09	26.06	43.18	25.32	62.50	4469	4169
5	6.64	33.82	25.67	38.23	58.62	4623	4323
6	5.39	28.86	34.85	30.9	76.09	3871	3571
7	8.24	33.96	8.84	53.16	61.23	4821	4521
8	13.15	24.95	33.57	28.38	48.69	4345	4045
9	11.18	25.07	39.85	24.58	65.93	4268	3968
10	4.45	27.87	36.19	31.51	60.37	5003	4703
11	6	26.74	28.1	39.16	57.49	4963	4663
12	5	29.01	37.6	28.7	70.32	3962	3662
13	2.4	23.27	52	22.6	57.28	3645	3345
14	4.45	25.01	44.02	26.68	76.65	3692	3392
15	8.39	31.4	33.42	27.81	52.33	4538	4238

Conclusion

It could be observed from this study that the coal samples collected for the study contain low to medium quantity of moisture, medium to high amount of volatile matter and high amount of ash in general. The grindability index of majority of the coal samples being low they are vey difficult to grind as well. The calorific values of the coals vary between 3345 kcal to 4703 kcal. A few of these coals could be washed easily, but for majority of the samples the washing problem varies between very difficult to formidable. Thus all these coals could be used ion thermal power plants and in other small scale industries for combustion purposes. However, proper pollution control arrangements are required to made since these coals are expected to give rise to huge amount of noxious pollutants during burning, because the ash content of the coals are very high.

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Indian Standard: 13810, 1993, Code of Practice for Float and Sink analysis of Coal, Bureau of Indian Standards, New Delhi.

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Chapter 1

INTRODUCTION

OBJECTIVE

1. INTRODUCTION

Coal is the world's most abundant and widely distributed fossil fuel. It is a global industry that makes a significant economic contribution to the global economy. Coal is mined commercially in more than 50 countries and used in more than 70. Annual world coal consumption is about 5,800 million tons, of which about 75% is used for electricity production. This consumption is projected to nearly double by the year 2030 to meet the challenge of sustainable development and a growing demand for energy.

Although coal deposits are widely distributed, more than 58% of the world's recoverable reserves are located in four Partners: the United States (27%), China (13%), India (10%) and Australia (8.7%). By rank, anthracite and bituminous coal account for 53% of the estimated recoverable coal reserves (on a tonnage basis), sub-bituminous coal accounts for 30%, and lignite accounts for 17%. In 2004, these four countries, taken together, accounted for about 64% of total world coal production. Partners consume about 65% of the total world production with Japan (183Mt) and South Korea (79Mt) being the world's two largest coal importers for electricity generation and steel production. Coal produces 40% of the world's electricity, which is double the share of its nearest competitors (gas and hydro) and coal is an essential element in over 65% of the world's steel production. These proportions are expected to remain at similar levels over the next 30 years.

The International Energy Agency (IEA) predicts that world energy demand will grow around 60% over the next 30 years, most of it in developing countries. China and India are very large countries in terms of both population and land mass, and both have substantial quantities of coal reserves. Together, they account for 70% of the projected increase in world coal consumption. Strong economic growth is projected for both countries (averaging 6% per year in China and 5.4% per year in India from 2003 to 2030), and much of the increase in their demand for energy, particularly in the industrial and electricity sectors, is expected to be met by coal.

Even as demand grows, society expects cleaner energy with less pollution and an increasing emphasis on environmental sustainability. The coal industry recognizes it must meet the challenge of environmental sustainability; in particular it must reduce its greenhouse gas emissions if it is to remain a part of a sustainable energy future. The quality of coal need to be assessed so that it can be suitably used in different industries. The mineral matter content and its type will give an idea about the coal preparation practice that will be required to be adopted for its cleaning and subsequent use. The knowledge of plastic properties of coal will give an idea about its suitability of use in steel industries. Investigation of physical properties such as hardgrove grindability index will help in deciding the type and capacity of crushing and grinding machine required in coal beneficiation plants. Spontaneous heating susceptibility studies of coal will help in deciding the coal in a judicious manner such that the coal is utilized before it catches fire. Keeping this in view the current work has been envisaged to analyze various coal samples taken from different mines and find out its properties, so that it can be utilized in optimum way.

1.1 OBJECTIVE

The objective of this project work is to analyze the quality of various Indian Coals and find out the suitability of different types of coals for different types of industries. Also coal sample analysis helps in determining the rank of the coal along with its intrinsic characteristics. Furthermore, these data will be used as the fundamental consideration for future concerns, for instance coal trading and its utilizations. Keeping this in view the objectives of the project work has been formulated as:

- Collection of coal samples from different mines
- Determination of different properties of coal samples in the laboratory by
    - proximate analysis
    - hardgroove grindability analysis
    - calorific value by bomb calorimeter method, and
    - float and sink analysis.
- Analysis of results of the experiments to find out their suitability for use in different industries.

Chapter 2

SAMPLE COLLECTION

SAMPLING PROCEDURE

2. SAMPLE COLLECTION

Any sample, even the most simple, brings with it a cascade of possible errors, some of which are related to the structure of the ore, and some to its distribution and its texture, with still others resulting from the particular sampling technique used, from the way the technique is applied or from the sampling apparatus used.

A collection of samples should be typical of a coal mass, otherwise it will be a collection of specimens. The word “sample” ordinarily denotes something that has been physically removed from its natural location to be tested in the laboratory. The experience of the professional, in sampling thousands of mines, provides a basis for deciding what the proper position and spacing should be, subject, of course, to modification for any individual mine after taking preliminary samples. This experience has developed methods, which eliminate, so far as possible, the personal element in selecting the material that is to constitute the sample. The standard methods of sampling include the use of various types of drills. The conventional method of doing this is by channel sampling.

2.1 SAMPLING PROCEDURE

For collection of coal samples, channel sampling procedure was followed. The following procedure was used to collect channel samples of coal.

- A freshly exposed coal surface was selected to sample. Coal ribs or Faces that had been “rock dusted “ or showed obvious signs of oxidation was avoided.In a deep mine sampling of a new face may be possible just after the roof has been bolted and before the next cut is made. In a surface mine a fresh face can be sampled following the loading stage of mining.
- A face having plain was selected that was normal to bedding. Coal migh be cut back with a hand pick at the top and bottom to produce a proper surface.
- 3 – `4 – m nylon – reinforced vinyl tarpaulin was spread on the floor.
- 2 parallel, vertical lines using (crayon) about 10 cm apart were marked on the coal surface.The units to be included in the sample were selected. If the exclusionary procedure was to be followed, then the excluded layers should have been marked.

- Using a pick, digging was started at the bottom of the coal bed and the coal between the lines to a depth of approximately 8 cm was chipped out; The steps were repeated from bottom to the top of the channel.
- Carefully the back of the channel was squared so that the channel cut was of uniform volume. In surface mines , gas powdered masonry cut off saws might be used to cut small channels on either side of the 10 cm wide block to be sampled. In deep mines an analogous procedure involves drilling a series of holes by hand augur, from top to bottom, on both sides of the 10 cm wide block to expose a column for sampling.
- The entire sample was transferred into polyethylene – line canvas bags or drums. Representative splitting could be done later in the laboratory.
- A properly marked sample tag was placed inside the innermost bag and the outside container was labeled and each container was separately sealed.

All the samples were collected following the above procedure. A total of 15 no. of coal sampels were collected from four different coalfileds, viz. Talcher and Ib Valley (Mahanadi Coalfields Ltd.), Talabira (Hindalco) and Chirimiri (South Eastern Coalfields Ltd.).

Chapter 3

COAL PROPERTIES AND THEIR TESTS

CHEMICAL PROPERTIES

PROXIMATE ANALYSIS

ULTIMATE ANALYSIS

PHYSICAL PROPERTIES

THERMAL PROPERTIES

PLASTIC PROPERTIES

3. COAL PROPERTIES AND THEIR TESTS

The utility of a particular coal for different purposes is based on different properties. These properties are chemical, physical, plastic, thermal and special properties. These properties are determined by a number of tests. The different properties and different tests carried out to determine these properties have been discussed in this chapter.

3.1 CHEMICAL PROPERTIES

Coal comes in four main types or ranks: lignite or brown coal, bituminous coal or black coal, anthracite and graphite. Each type of coal has a certain set of physical parameters which are mostly controlled by moisture, volatile content (in terms of aliphatic or aromatic hydrocarbons) and carbon content.

Moisture: It is an important property of coal, as all coals are mined wet. Groundwater and other extraneous moisture is known as *adventitious moisture* and is readily evaporated. Moisture held within the coal itself is known as *inherent moisture* and is analyzed quantitatively. Moisture may occur in four possible forms within coal:

- *Surface moisture*: water held on the surface of coal particles or macerals
- *Hydroscopic moisture*: water held by capillary action within the microfractures of the coal
- *Decomposition moisture*: water held within the coal's decomposed organic compounds
- *Mineral moisture*: water which comprises part of the crystal structure of hydrous silicates such as clays

Total moisture is analyzed by loss of mass between an untreated sample and the sample once analyzed. This is achieved by any of the following methods;

1. Heating the coal with toluene
2. Drying in a minimum free-space oven at 150 °C (300 °F) within a nitrogen atmosphere
3. Drying in air at 100 to 105 °C (210 to 220 °F) and relative loss of mass determined

Methods 1 and 2 are suitable with low-rank coals but method 3 is only suitable for high-rank coals as free air drying low-rank coals may promote oxidation. Inherent moisture is analysed similarly, though it may be done in a vacuum.

Volatile Matter: Volatile matter in coal refers to the components of coal, except for moisture, which are liberated at high temperature in the absence of air. This is usually a mixture of short and long chain hydrocarbons, aromatic hydrocarbons and some sulfur. The volatile matter of coal is determined under rigidly controlled standards. Any coal which has high volatile matter content:

- Can ignite easily.
- Burns with long smoky yellow flame.
- Has low calorific value.
- Needs large furnace volume for combustion.
- High tendency of catching fire.

Ash: Ash content of coal is the non-combustible residue left after coal is burnt. It represents the bulk mineral matter after carbon, oxygen, sulfur and water (including from clays) has been driven off during combustion. Analysis is fairly straightforward, with the coal thoroughly burnt and the ash material expressed as a percentage of the original weight.

Mineral Matter: There are two types: (1) Inherent (2) Extraneous

- Inherent comes from inorganic constituent of plant materials, but the amount is less.
- Extraneous comes from the amount that gets associated with substances during its conversion process. These are associated with internal structures and amount is high. It is difficult to remove them.

Relation between mineral matter and ash is given below:

$$M.M = 1.08Ash + 0.555$$

For Indian coals:

$$M.M = 1.1Ash$$

Coal containing high ash is:

- Harder and Stronger.
- Low calorific value.
- Will produce slag.
- Clinker formation.

Fixed Carbon: The fixed carbon content of the coal is the carbon found in the material which is left after volatile materials are driven off. This differs from the ultimate carbon content of the coal because some carbon is lost in hydrocarbons with the volatiles. Fixed carbon is used as an estimate of the amount of coke that will be yielded from a sample of coal. Fixed carbon is determined by removing the mass of volatiles determined by the volatility test, above, from the original mass of the coal sample.

The above parameters are determined by proximate analysis. The elemental constituents of coal are carbon, hydrogen, nitrogen, sulphur and oxygen and these are determined by ultimate analysis.

3.1.1 Proximate Analysis

Determination of moisture, volatile-matter, ash and fixed carbon in coal comprises its proximate analysis.

Determination of moisture content: Loss in weight of coal caused by heating of coal sample for one hour at 105˚C is the moisture content of coal. A known amount of finely powdered coal sample is kept in a silica crucible and heated in a muffle furnace at 105-110˚C for one hour. There after the crucible is taken out, cooled in a dessicator and weighed. The percentage of moisture is given by

% moisture in coal = {loss in wt. of coal X 100}/ wt. of coal initially taken

Determination of Volatile Matter: It is the loss in weight of moisture free powdered coal when heated in a crucible fitted with cover in a muffle furnace at 925˚C for 7 minutes.

% volatile matter ={ loss in wt. of moisture free coal X 100}/ wt. of moisture free coal taken

Determination of Volatile Matter: It is the weight of residue obtained after burning a weighed quantity of coal in an open crucible (i.e. in presence of air) at 750˚C in a muffle furnace till a constant weighed is achieved.

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

Determination of Fixed Carbon: It is determined indirectly by deducting the sum total of moisture, Volatile matter, and ash percentage from 100.

% fixed carbon in coal = 100-(% moisture+% ash+% volatile matter)

3.1.2 Ultimate Analysis

Determination of total carbon, hydrogen, nitrogen, oxygen and sulphur percentages in coal comprises its ultimate analysis.

Determination of Carbon and Hydrogen in coal: A known amount of coal is burnt in a current of dry oxygen thereby converting C and H of coal into CO_2 and H_2O respectively. The products of combustion (CO_2 and H_2O) are passed over weighed tubes of anhydrous CaCl and KOH which absorbs H_2O and CO_2 respectively. The increase in the weight of $CaCl_2$ tube represents the weight of water (H_2O) formed while increase in the weight of KOH tube represents the weight of CO_2 formed.

% of H and C in can be calculated as follows as given below :

Let, $X =$ wt. of coal sample taken,

$Y =$ Increase in the wt. of $Cacl_2$ tube

$Z =$ Increase in the wt. of KOH tube

Amount of carbon in the coal sample = $Z \times \frac{12}{44}$

% carbon in coal = $100 \times \frac{12Z}{44X}$

Similarly, amount of hydrogen in coal sample = $\frac{2Y}{18}$

% hydrogen in coal = $100 \times \frac{2Y}{18X}$

Determination of Nitrogen: It is done by kjeldahal's method. A known weight of powdered coal is heated with conc. H_2SO_4 in presence of Potassium sulphate and Copper sulphate in a long necked flask there by converting nitrogen of coal to ammonium sulphate.When clear solution is obtained it is treated with 50% NaOH solution. The ammonia thus formed is distilled over and absorbed in a known quantity of standard sulphuric acid solution. The volume of unused H_2SO_4 is then determined by titrating against standard NaOH solution. Thus, the amount of acid neutralized by liberated ammonia is determined.

%of nitrogen in coal = {vol. of acid used X Normality X 1.4} / wt. of coal taken

Determination of Sulphur: A 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 precipated as sulphates.The sulphate formed is precipitated as $BaSO_4$ (by treating with $BaCl_2$).

% of sulphur in coal = $100 \times 0.1374 \frac{y}{x}$

Where, $x =$ weight of coal sample taken

$y =$ Weight of $BaSO_4$ precipitate formed

Determination of Oxygen: It is deduced indirectly as follows.

% of oxygen in coal = 100 – (% of C +H+N+S+ash)

3.2 PHYSICAL PROPERTIES

Specific Gravity: The proportion and nature of both the organic mass and mineral matter influence the specific gravity of coal. For the same type of coals, the higher ash coals have higher specific gravity. The true specific gravity of bituminous coals varies between 1.27 & 1.45. The following formula is valid for many coals of India.

$$S = k + \frac{A}{100}$$

Where ,

$S =$ Specific gravity

$A =$ Percentage of Ash

$k =$ a constant, value is 1.25

The above formula assumes an overall specific gravity of 2.25 for the mineral matter of coal.

Densities: Partly due to the intricately structured void volume of coal, its density not only varies with rank, but also depends on how it is measured. “Coal density” therefore carries several different connotations, and a distinction must, in particular, be made among Bulk densities which are determined by the average particle (or lump) size, size distribution, and packing density of the coal, and bear on handling, transportation, and storage.

In-place densities which refer to the weight-to-volume ratios of undisturbed coal in their respective seams and are important parameters for estimating coal reserves. Apparent specific densities which are measured by displacement of liquid and depend on the molar volume of that liquid. Absolute densities which are the putative “true” densities of the organic coal substance in its various stage of metamorphic development.

Angle of Repose: It is the angle that the heap of coal forms with the horizontal and is of importance in its storage and in its flow in the conveyors and feed hoppers. It may vary by 2-3 degrees depending upon the roughness of the surface, moisture content etc. In general the higher the sizes of coal, the higher the angle of repose. This means that a larger bulk of bigger sizes coal may be stored in a heap of given height.

Specific Heat: The specific heat of coal increases with increase in the volatile matter and decrease in the C/H ratio. The relationship between specific heat and moisture is linear.

Porosity, Surface area and Heat of Wetting: Few properties influence coal behavior more immediately and directly than Pore space. Even in Anthracites this is always so extensive and so intricately structured as to make coal something like a solid sponge and endow it with the characteristics of a solid colloid.

Heat of wetting is a measure of surface area of coal. Porosity, Surface area and Heat of Wetting vary with the rank of coal on the same manner as the moisture varies with the rank.

Hard-Grove Grindability Index of Coal: It gives an idea about the relative ease of grinding coals or the power required for grinding coals in a pulverizer. A standard test called Hard-Grove method is employed to determine the Hard-Grove grindability index.

50gms of air dried coal size –16+30 mesh is subjected to 60 revolutions in a small mill (miniature pulveriser). After grinding, the coal is screened the coal is screened through a 200 mesh sieve. Hard-Grove grindability index (HGI) is then calculated as

$$G = 6.93W + 13$$

Where W = weight of sample passing through the 200 mesh sieve, in gm

Coals which are easy to grind have an index near to 100. The 2 methods to determine the ease of grinding are ball mill method and Hard-Grove method. A high value of G indicates a soft and easily grindable coal. HGI of coal initially increases with the rank, reaches a maximum of about 105 for bright coals of 89-90% carbon, and then falls sharply to about 35 for anthracites. The average HGI for Indian coals is 55-65 but coking coals of Jharia and Giridih show value up to 75.

3.3 THERMAL PROPERTIES

When a sample of powdered coal is heated out of contact with air, it loses occluded gases consisting of methane, ethane, nitrogen, carbon dioxide etc at temperatures below 100˚C. Moisture is evolved between 100˚C and 150˚C. The initial temperature of decomposition of bituminous coals is 200-300˚C while active decomposition starts at 300-375˚C for these coals.

Pyrogenic water, primary tar and gases evolve during the primary devolatilization (at 300-550˚C), while gases (mainly hydrogen) are evolved during the secondary devolatilization at around 700˚C. While coal undergoes decomposition on heating, the residue becomes richer in carbon content. In the case of caking coals, the residue passes through a plastic state in the range 300-350˚C to 500-550˚C.The fluidity of the plastic mass initially increases, attains a maximum and then decreases to zero. If coke is heated further, significant changes take place around 2000˚C when graphite like materials results. This process is called graphitization and is used in the production of graphite electrode and other articles. Non-caking coals are not amenable to graphitization.

The porosity of coal decreases on heating and attains a minimum in the plastic state. After resolidification, porosity again rises considerably, The porosity of coke is 40% or above. This property ensures smooth burning of coke in furnaces. Because of the simultaneous formation of the plastic state and volatile products of thermal decomposition, the carbonaceous residue exhibits an initial contraction and fall in porosity followed by swelling, dilation and rise in porosity.

3.4 PLASTIC PROPERTIES

When coal is heated, it passes through a transient stage which is called as plastic state (caking). If a particular coal does not pass through a plastic state, it is called sintered mass(non-coking).Plastic properties of coal is determined by caking index test, free swelling test, GKLT, Plastometer.

Caking Index: It is the measure of binding or agglutinating property of coking coal. Numerically it is the maximum number ratio of sand to coal in a 25gm mixture of the two (Sand + Coal) which on heating under standard conditions produces a residue coke capable of supporting a weight of 500gms without producing more than 5% of loose grains of coke.

The Caking Index of coal blend charge for coke ovens is about 21 to 22. If the coal has higher than 17%ash, it has to be washed before testing.

Free Swelling Index: It denotes the caking capacity of coal. In this test 1gm of (-212μ) coal samples are taken and heated in a silica crucible of particular dimension. It is heated in a burner or in a furnace maintained at 825-850˚C.Heating is carried out for 4 minutes. Maximum value of free swelling index is 9. Coal having free swelling index between 4-5 are taken for coke making.

Gray King Low Temperature Assay (GKLT): It is carried out to observe coking property of coal.First, 20gm of fine coal of -212μ size is taken in a silicon crucible and then the furnace is pre-heated at 300˚C. Heating is carried at a rate of 5˚C/minute till the temperature reaches 575˚C, & then increased to 600˚C quickly. At 600˚C hold it for 15 minutes. After that detach the apparatus. The profile inside the crucible is compared with standard coal burden from A-G, G_1, G_2….G_9, G_{10}.

A	-	The residue is powder with no swelling
B	-	Non coking,
C & D	-	weakly caking,
E,F & G	-	medium caking,
G_1- G_9	-	High caking.

After heating the sample hard mass obtained = Vol. of the coal sample

Then it is ‘G’. The suffix 1, 2, 3 indicates the no. of grams of inert ‘C’ required to be added to the hard mass to give the original profile or standard G-type coke.

Chapter 4

EXPERIMENTAL INVESTIGATION

PROXIMATE ANALYSIS

DETERMINATION OF HGI

DETERMINATION OF CALORIFIC VALUE

WASHABILITY STUDIES

4. EXPERIMENTAL INVESTIGATION

4.1 PROXIMATE ANALYSIS

Determination of Moisture Content (M*)*

About 1 gram of finely powdered (-212µ) air dried coal sample was weighed in a silica crucible and was then placed inside an electronic hot air oven, maintained at 108±2˚C. The crucible with the coal sample was allowed to remain in the oven for 1.5 hours and was taken out with a pair of tongs cooled in a dessicator for about 15 minutes and then weighed. The loss in weight is reported as moisture(on percentage basis). The calculation is done as per the following :

$$\% \text{ moisture} = \% \text{ M} = \frac{Y-Z}{Y-X}\times 100$$

Where, $X =$ Wt of crucible in gms

$Y =$ Wt of coal + Crucible in gms(Before in heating)

$Z =$ Wt of coal + Crucible in gms(After in heating)

Determination of Volatile Matter content (VM)

About 1 gram of finely powdered (-212µ) air dried coal sample was weighed in a VM crucible and was then placed inside a muffle furnace maintained at 925˚C. The crucible was then covered with its lid. The heating was carried out for exactly 7 minutes, after which the crucible was removed, cooled in air and then in a desiccators and weighed again. The calculation is done as per the following:

$$\% \text{ V.M} = \frac{Y-Z}{Y-X}\times 100$$

Where $X =$ Wt of crucible in gms

$Y =$ Wt of coal + Crucible in gms(Before in heating)

$Z =$ Wt of coal + Crucible in gms(After in heating)

Determination of Ash content (Ash)

About 1 gram of finely powdered (-212µ) air dried coal sample was weighed and taken in an empty silica crucible. Before that the crucibles were heated at 800˚C for about 1 hr to remove any foreign particles in the crucible. The crucible along with the sample was put in a muffle furnace at 450˚C for about 30 minutes. After that the temperature of the furnace was raised to 850˚C and the sample was heated for about 1 hr at that temperature. The calculation is done as per the following:

$$\% \text{ Ash} = \frac{Z - X}{Y - X} \times 100$$

Where $X =$ Wt of crucible in gms

$Y =$ Wt of coal + Crucible in gms(Before heating)

$Z =$ Wt of coal + Crucible in gms(After heating)

Determination of Fixed Carbon (C)

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

%C = 100 – (%M+%VM+% Ash)

The results of proximate analysis for all the coal samples are presented in Table 4.1.

Table 4.1: Proximate Analysis of Coal Samples

SAMPLE NO.	MOISTURE (%)	VOLATILE MATTER (%)	ASH (%)	FIXED CARBON (%)
1	4.5	25.04	34.56	24.6
2	6.65	28.25	26.92	34.92
3	5.24	25.01	33	37.1
4	5.09	26.06	43.18	25.32
5	6.64	33.82	25.67	38.23
6	5.39	28.86	34.85	30.9
7	8.24	33.96	8.84	53.16
8	13.15	24.95	33.57	28.38
9	11.18	25.07	39.85	24.58
10	4.45	27.87	36.19	31.51
11	6	26.74	28.1	39.16
12	5	29.01	37.6	28.7
13	2.4	23.27	52	22.6
14	4.45	25.01	44.02	26.68
15	8.39	31.4	33.42	27.81

4.2 DETERMINATION OF HARDGROVE GRINDABILITY INDEX

The grindability of Coal is a measure of the ease with which it can be ground fine enough for use as a pulverised fuel, & it also shows the physical properties of coal like hardness, tenacity and fracture. There is a fixed relationship between Grindability and rank of coal in the natural series from brown coal to lignite & anthracite. Coals easier to grind have 14 to 30 percent volatile matter. Coals with higher volume matter are more difficult to grind. However petrographic & mineral constituents influence grindability. The hardgroove index of coal is affected by its moisture content and hence on the humidity of the atmosphere in which the test is carried out.

Experimental Procedure

1 kg of coal sample was taken and crushed to pass through 4.75mm sieve. The resulting sample was put in two sieve of 1.18mm sieve (upper sieve) and +600µ size(lower sieve). Sieve the material for 2 minutes until the entire material pass through 1.18mm sieve. The 1.18mm by 600µ size coal was mixed thoroughly and 120 gm of the sample was removed for sample divider.

The 50gm sample was taken in a ball mill along with 8 iron balls with diameter 25.4±0.003 mm. The mouth of the ball mill was closed and it was set to rotate for about 60 revolutions, when the rotation is achieved, the machine was stopped.

The sample left in the ball mill was then collected along with any powdered substance sticking to the surface of the machine by help of a brush. This sample was then put in a sieve of 75µ size and was shaken for about 10 minutes.

After sieving for about 5 minutes, the sample which passes through 75µ size was weighed on the balance.

Calculation - The hard groove grindability index of coal is calculated using the following formula.

$$HGI = 13 + 6.93\ W$$

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

Table 4.2 gives the grindability index of all the coal samples that were collected for the study.

Table 4.2: Values of HGI of the Coal Samples

SAMPLE NO.	Hardgrove Grindability Index(HGI)
1	68.54
2	59.22
3	65.203
4	62.50
5	58.62
6	76.09
7	61.23
8	48.69
9	65.93
10	60.37
11	57.49
12	70.32
13	57.28
14	76.65
15	52.33

4.3 DETERMINATION OF CALORIFIC VALUE OF COAL BY BOMB CALORIMETER

The bomb calorimeter consists of a strong stainless steel vessel, called bomb, capable of withstanding high pressures. The bomb is provided with a lid which can be screwed firmly on the bomb. The lid in turn is provide with two electrodes and an oxygen inlet valve. One of the electrodes is provided with a ring to accommodate the silica crucible. The bomb is placed in a copper calorimeter having a known weight of water. The copper calorimeter, in turn, is surrounded by an air jacket and a water jacket to prevent loss of heat due to radiation. The calorimeter is provided with an electrical stirrer for stirring water and a Beckmann's thermometer.

Experimental Procedure

A weighed amount of the fuel is placed in the silica crucible. The crucible is supported over the ring. A fine magnesium wire touching the fuel sample is stretched across the electrodes.

Oxygen supply is forced into the bomb till a pressure of 25-30 atm is reached. Initial temperature of the water in the calorimeter is noted after thorough stirring. The current is switched on the fuel in the crucible burns with the evolution of heat. The heat produced by the burning of fuel is transferred to water which is stirred throughout the experiment by the electric stirrer. Maximum temperature shown by the thermometer is recorded. The calorific value of the fuel can now be calculated as below.

OBSERVATION:

Wt. of the fuel taken in crucible = x kg

Wt. of water in calorimeter = y kg

Water equivalent of the calorimeter, stirrer, thermometer & bomb = z kg

Initial temperature of water in calorimeter = t_1 ˚C

Final temperature of water in calorimeter = t_2 ˚C

Let, the higher (gross) calorific value of the fuel = C kcal/kg

CALCULATIONS:

Heat gained by water = $y \times (t_2 - t_1)$ kcal

Heat gained by calorimeter = $z \times (t_2 - t_1)$ kcal

Total heat gained = $y(t_2 - t_1) + z(t_2 - t_1)$ kcal = $(y + z)(t_2 - t_1)$ kcal

Heat liberated by coal = $x \times C$ kcal

Now, Heat liberated by coal = Heat gained by water + calorimeter

i.e. $x \times C = (y + z)(t_2 - t_1)$

So, Gross Calorific Value = ***C*** = $\frac{(y + z)}{x}(t_2 - t_1)$ *kcal/kg*

Now, Lower (net) Calorific value of coal = Higher calorific value – Latent heat of water vapour formed

$= C - 0.09H \times 587$ K Cal/Kg

G =Net Calorific Value $= C - 300$

Where, 300 = the heat consumed by fuse wire + cotton + the latent heat of water vapour formed.

Table 4.3. gives the net calorific values and gross calorific values of the samples collected.

Table 4.3: Calorific Values of Coal Samples

SAMPLE NO.	Gross calorific value (Kcal)	Net calorific value (Kcal)
1	3896	3596
2	4558	4258
3	4796	4496
4	4469	4169
5	4623	4323
6	3871	3571
7	4821	4521
8	4345	4045
9	4268	3968
10	5003	4703
11	4963	4663
12	3962	3662
13	3645	3345
14	3692	3392
15	4538	4238

4.4 WASHABILITY CHARACTERISTICS

The raw coal contains impurities after its primary sizing operations. It contains the minerals matter with which it was associated underground and some other materials getting mined up during handling. But these should not be operation by which coal is cleaned is known as coal cleaning. The properties which are used in coal cleaning are specific gravity, shape and size of the particles, friction, resilience, surface tension etc.

Cleaning process generally depends upon differences in density between clean coal and its impurities. They suitably remove the free dirt but not the inherent dirt. The extent of removal of free dirt on the amenability of a coal to improvement in quality is more commonly known as the “washability” of coal and is more commonly indicated by the “float and sink” analysis of coal. These washability investigations are conducted before average proposal for installation of a coal washery is considered.

Experimental Procedure

A coal sample of (-2+1) size is taken and of which 100g is weighed. Liquids of different specific gravity varying from 1.3 to 1.8 are prepared using CCl_4, benzene and water in different concentrations. The liquids are taken in fuel jars and arranged in the order of increasing specific gravities (1.3, 1.4 … and so on). The sample is first placed in the lowest specific gravity liquid. The fraction higher than the liquid floats and heavier ore sinks. The portion which floats on a particular specific gravity and the portion which sinks is known as sink fraction. Then the sinks is placed in next higher specific gravity and the float and sink fractions separated. In this way, the float and sink fractions of different specific gravities are collected and weighed, taking care that no coal particles are lost. Determination of the ash content of coal the float and sink fractions are carried out and the results are tabulated. The washability curves are plotted taking total floats vs. ash, total sinks vs. ash and the washability characteristic curves on instantaneous ash curve.

Three curves are drawn. These are Total floats – Ash curve, Total Sinks – Ash curve & Washability Characteristic curve or Instantaneous Ash curve.

The representation of the above said curves are as follows :

Curve 1 - Total floats – Ash curve

Curve 2 - Total Sinks – Ash curve

Curve 3 - Instantaneous Ash curve

The advantage of drawing all the curves on a common diagram are that all the essential information required for studying the cleaning possibilities of a coal can be readily obtained by cross projections. For example, if one is interested to recover 15% ash clean coal, he has to read first from the total floats curve the percent yield of cleans corresponding to 15% ash. Then from this yield point, a horizontal line is drawn to cut the total sinks-ash curve, the ash content of the sinks is read from the ash-axis below and at the cut point of the yield- gravity cut, the required density of separation is read from the gravity axis above.

Interpretations from Graphs

- From curves 1 & 2 we can directly find out the yield and ash of the clean product & the heavy waste at a certain specific gravity of washing.
- If we want to know the specific gravity at which cleaning should be done to have maximum yield of clean coal within a certain upper limit of ash value, then Curve – 1 is consulted.

- Curve 3 shows how far it is possible to separate the dirt's from the clean coal by mechanical methods.
- For easily washable coal Curve 3 should have a sharp bend.
- In a very difficult coal the above is a straight line.

The specific gravity at which a coal is to be cleaned is determined from the washability data and economic considerations. The ease of washing at this specific gravity may be judged from the amount of near gravity material (ngm) present in the coal. The amount of this material is defined as the percentage of the coal that will float in a range within plus minus 0.10 specific gravity of the separation value. The presence of ngm causes misplacements of sinks in floats and floats in sinks. The larger the amount of ngm, the more difficult the cleaning operation, and vice versa. The following table shows the estimate of coal washing problem from the amount of near-gravity material.

Table 4.4: Estimation of coal washing problem from the amount of near-gravity material

Amount of ngm %		Estimate of coal washing problem
Greater than	Less than	
0	7	simple
7	10	Moderately difficult
10	15	Difficult
15	20	Very difficult
20	25	Exceedingly difficult
25	-	Formidable

Float and sink analysis were performed on all the 15 coal samples and their results have been presented in tables 4.5 to 4.19 and the washability curves have been presented in figures 4.1 to 4.15 respectively.

The following formulae were used for calculation of the yield of total sinks, ash of total sinks and cumulative yield upto the middle of fraction (CMF) for all the samples:

Yield of total sinks = 100 – yield of total floats

Ash of total sinks = {100*coal ash – total floats * ash of total floats} / Total sinks

CMF percent of fraction = Total floats upto fraction (F - 1) + ½(Yield of fraction, F)

Table 4.5: Float and Sink Test Results of Sample no.1

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	1.54	4.98	1.54	4.98	98.46	35.02	0.77
1.4	2.62	7.88	4.16	6.81	95.84	35.76	2.85
1.5	12.42	16.45	16.58	14.03	83.42	38.64	10.37
1.6	10.68	28.46	27.26	19.68	72.74	40.14	21.92
1.7	18.78	33.68	46.04	25.39	53.96	42.38	36.65
1.8	22.64	40.77	68.68	30.46	31.32	43.55	57.36
>1.8	31.32	56.42	100	38.59	-	-	84.34

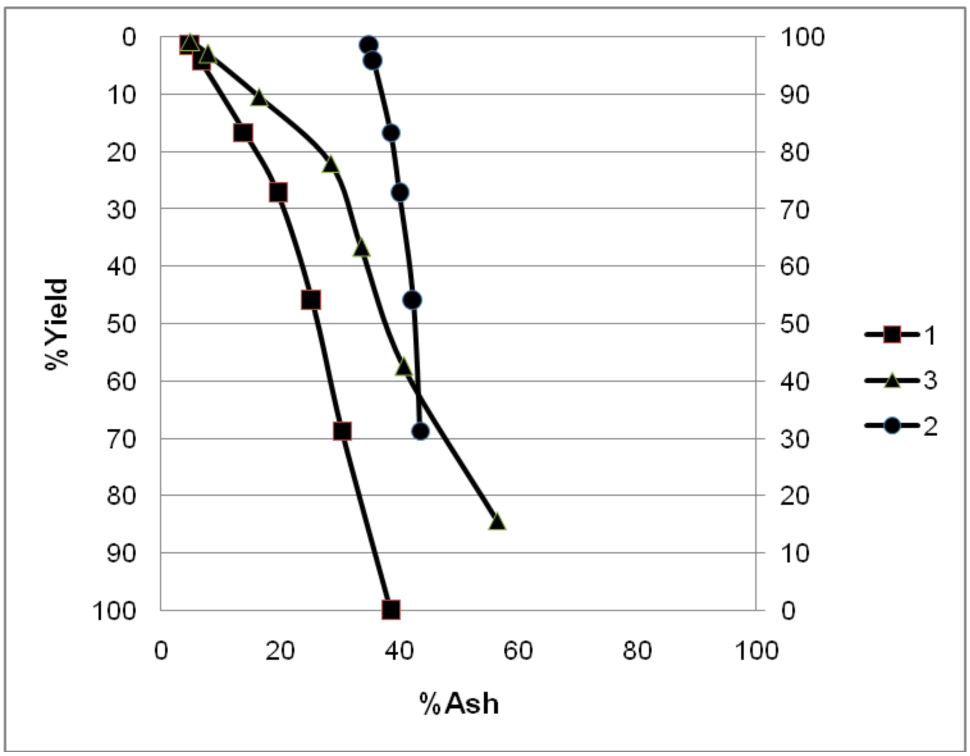

Figure 4.1: Washability Curves for Sample no.1

Table 4.6: Float and Sink Results of Sample no.2

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	4.62	6.64	4.62	6.68	95.38	27.9	2.31
1.4	27.22	14.88	31.84	13.68	68.16	33.11	18.23
1.5	22.66	22.61	54.5	17.4	45.5	38.32	43.17
1.6	19.58	30.34	74.08	20.82	25.92	44.36	64.29
1.7	10.34	41.5	84.42	23.35	15.58	46.26	79.25
1.8	12.48	50.92	96.9	26.9	3.1	48.33	90.66
>1.8	3.1	60.54	100	27.94	-	-	98.45

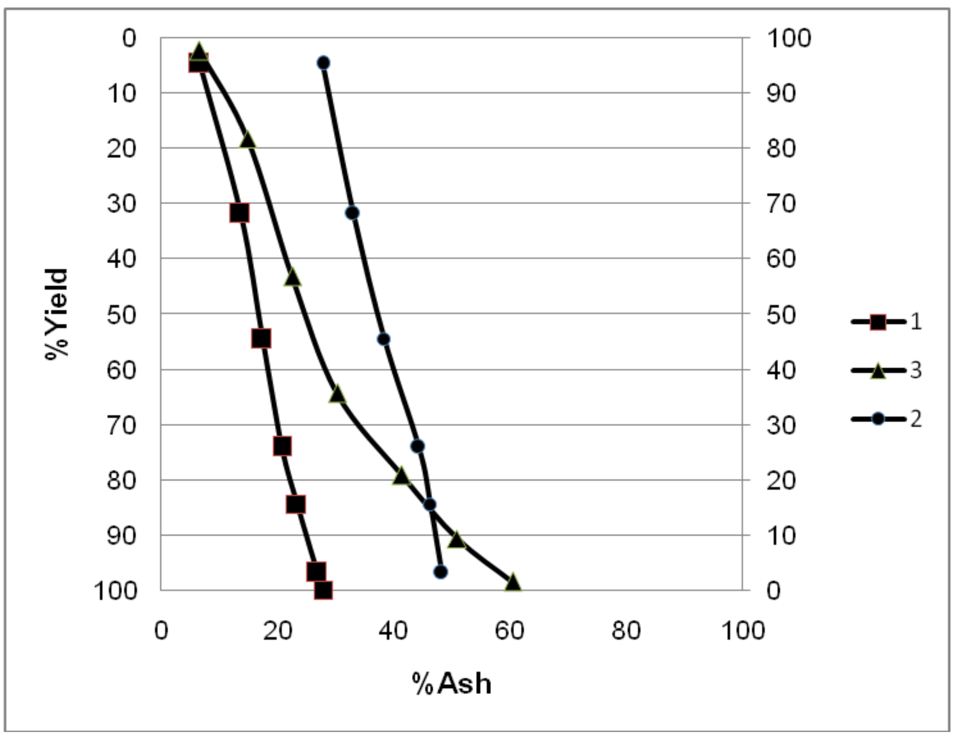

Figure 4.2: Washability Curves for Sample no.2

Table 4.7: Float and Sink Results of Sample no.3

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	3.56	6.21	3.56	6.21	96.44	33.98	1.78
1.4	11.62	9.11	15.18	8.42	84.82	37.39	9.37
1.5	12.22	17.88	27.4	12.64	72.6	40.68	21.29
1.6	13.42	29.31	40.82	18.12	59.18	43.26	34.11
1.7	14.43	34.15	65.25	24.12	34.75	49.67	53.04
1.8	13.55	44.83	78.8	27.68	21.2	52.77	72.03
>1.8	21.2	55.16	100	33.5	-	-	89.4

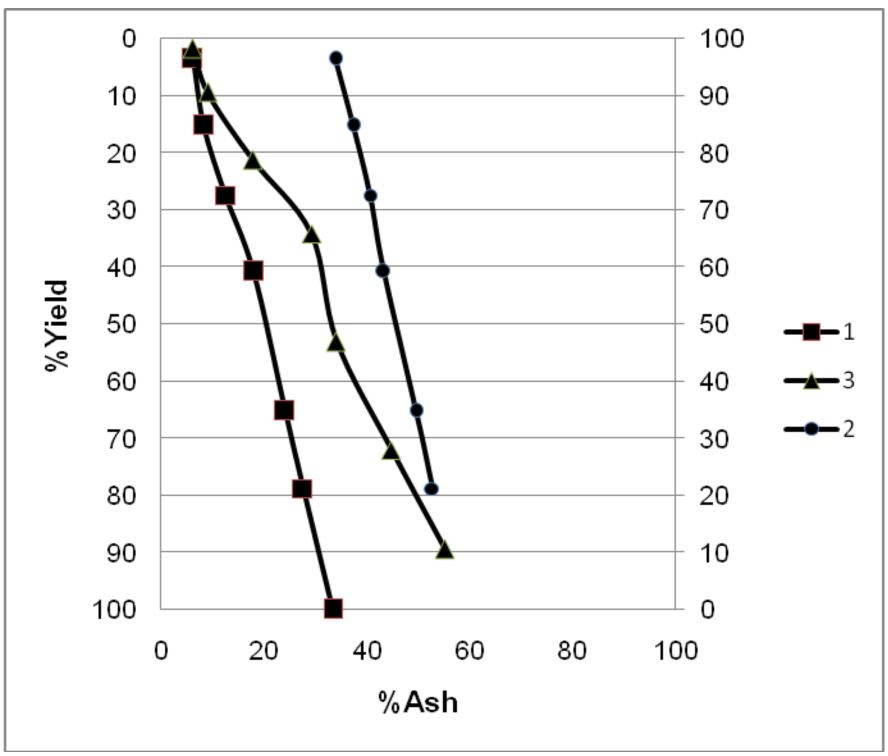

Figure 4.3: Washability Curves for Sample no.3

Table 4.8: Float and Sink Results of Sample no.4

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
1.3	1.44	5.48	1.44	5.48	98.56	43.73	0.72
1.4	5.28	11.94	6.72	10.56	93.28	45.53	4.08
1.5	8.92	24.2	15.64	18.34	84.36	47.78	11.18
1.6	12.14	33.67	27.78	25.04	72.22	50.16	21.71
1.7	8.36	42.58	36.14	29.09	63.86	51.15	31.96
1.8	28.56	48.74	64.7	37.77	35.3	53.15	50.42
>1.8	35.3	57.62	100	44.77	-	-	82.35

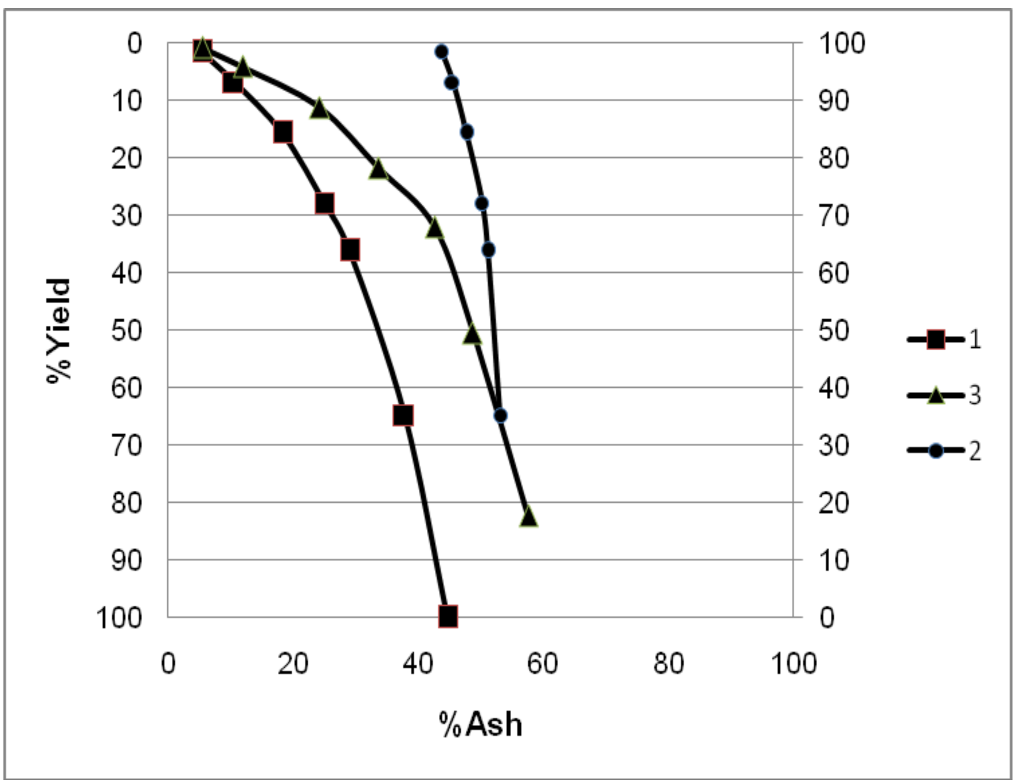

Figure 4.4: Washability Curves for Sample no.4

Table 4.9: Float and Sink Results of Sample no.5

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	6.35	9.52	6.35	9.52	93.65	26.76	3.18
1.4	24.32	14.75	30.67	13.67	69.33	30.98	18.51
1.5	22.66	24.61	53.33	18.32	46.67	34.07	42
1.6	23.18	32.89	76.51	22.73	23.49	35.25	64.92
1.7	6.96	40.44	83.47	24.21	16.53	37.52	79.99
1.8	8.48	49.63	91.95	26.55	8.05	39.63	87.71
>1.8	8.05	60.54	100	29.28	-	-	95.98

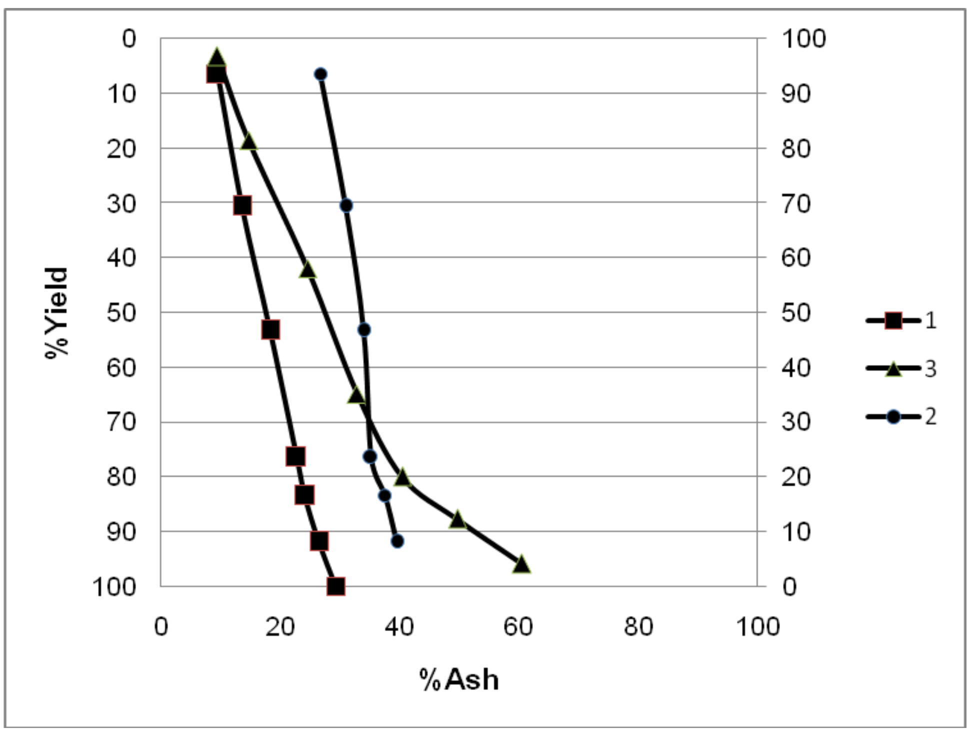

Figure 4.5: Washability Curves for Sample no.5

Table 4.10: Float and Sink Results of Sample no.6

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	11.49	7.66	11.49	7.66	88.51	38.38	5.75
1.4	4.02	14.68	15.51	9.48	84.49	39.51	13.5
1.5	29.68	24.32	45.19	19.23	54.81	48.28	30.35
1.6	23.77	37.77	68.96	25.62	31.04	55.36	57.08
1.7	8.98	46.62	77.94	28.04	22.06	58.91	73.45
1.8	9.62	33.54	87.56	30.84	12.44	63.07	82.75
>1.8	12.44	64.86	100	35.07	-	-	93.78

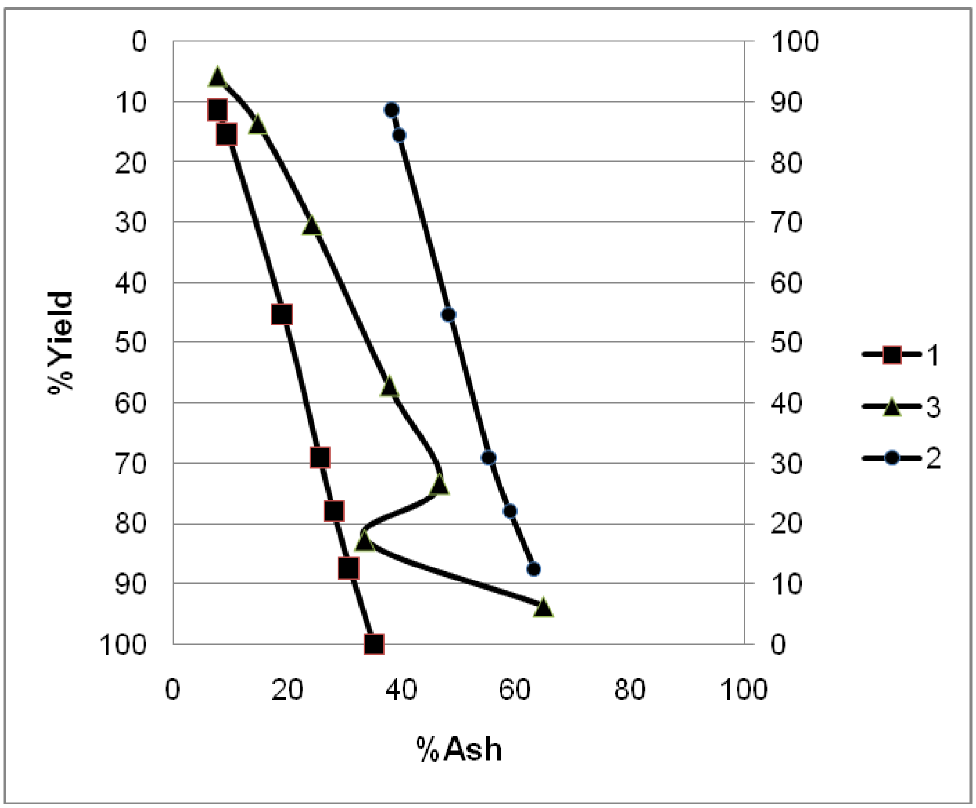

Figure 4.6: Washability Curves for Sample no.6

Table 4.11: Float and Sink Results of Sample no.7

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	25.63	5.78	25.63	5.78	74.37	9.89	12.82
1.4	23.96	7.35	49.59	6.54	50.41	11.1	37.61
1.5	30.15	10.73	79.74	8.12	20.26	11.67	64.67
1.6	18.32	18.42	98.04	10.06	1.94	12.32	88.9
>1.6	1.94	23.62	100	10.33	-	-	99.01

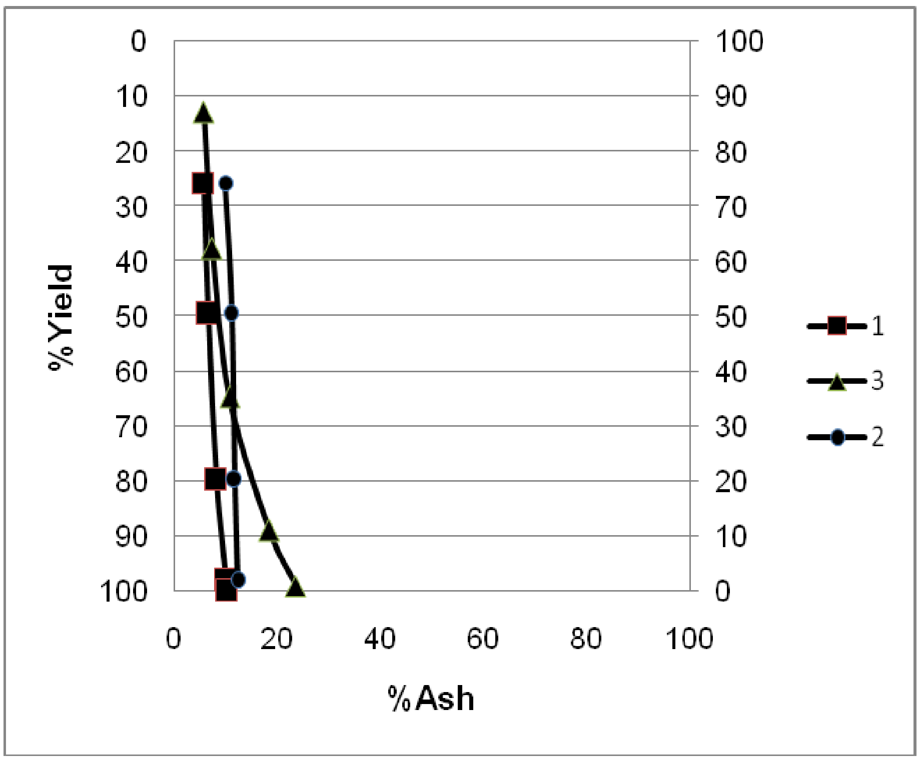

Figure 4.7: Washability Curves for Sample no.7

Table 4.12: Float and Sink Results of Sample no.8

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	4.62	4.24	4.62	4.24	95.38	34.99	2.31
1.4	11.21	12.67	15.83	10.21	84.17	37.96	10.23
1.5	25.33	27.48	41.16	20.84	58.84	42.47	28.5
1.6	28.92	38.49	70.08	28.12	29.92	46.34	55.62
1.7	12.66	47.1	82.74	31.03	17.26	48.75	76.41
1.8	4.33	56.15	87.07	32.28	12.93	52.68	84.91
>1.8	12.93	67.88	100	36.88	-	-	93.54

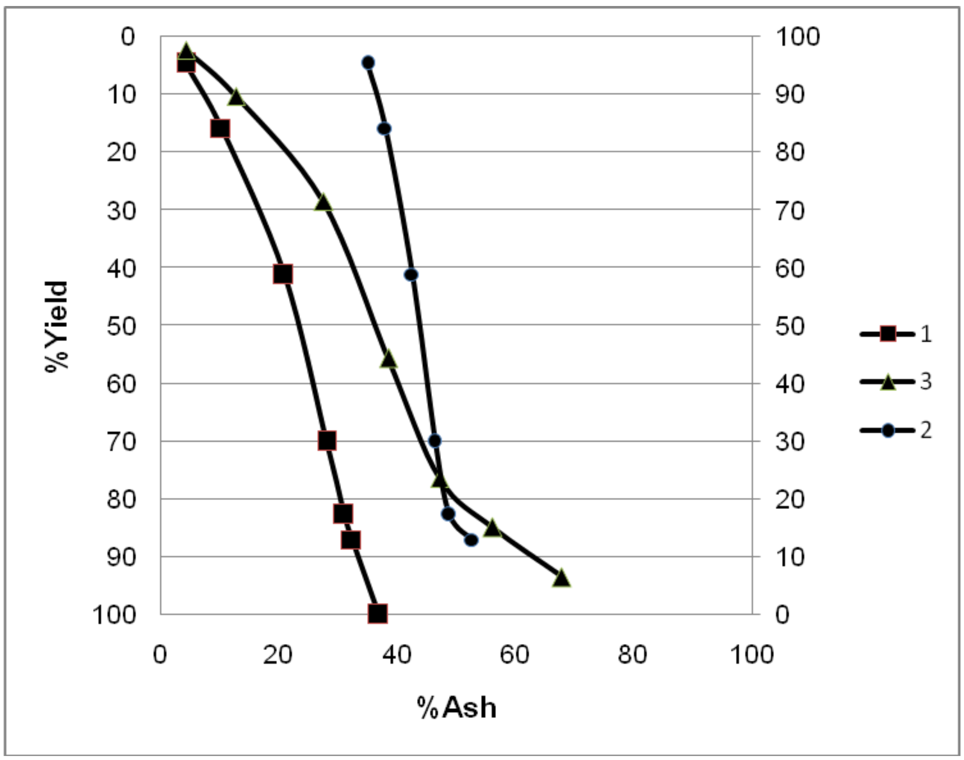

Figure 4.8: Washability Curves for Sample no.8

Table 4.13: Float and Sink Results of Sample no.9

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	2.57	4.97	2.57	4.97	97.43	40.77	1.29
1.4	4.86	11.63	7.43	9.33	92.57	42.3	5
1.5	10.11	19.37	17.54	15.12	82.46	45.11	12.49
1.6	9.68	29.44	27.22	20.21	72.78	47.2	22.38
1.7	22.57	40.62	49.79	29.46	50.21	50.15	38.51
1.8	27.82	51.77	77.61	37.46	22.39	53.61	63.7
>1.8	22.39	62.47	100	43.05	-	-	88.81

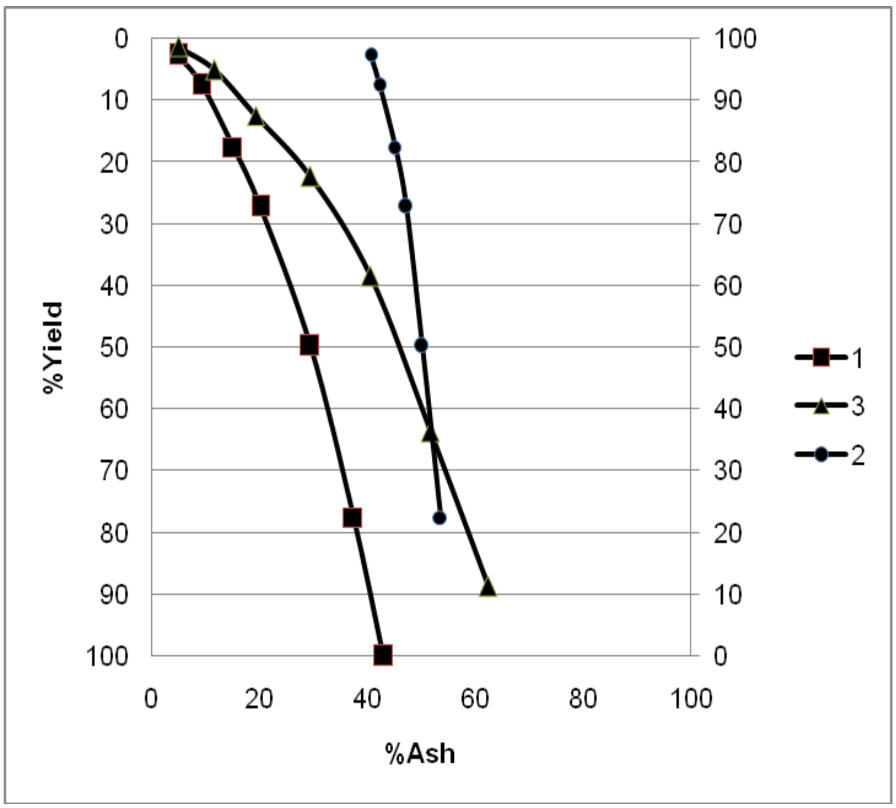

Figure 4.9: Washability Curves for Sample no.9

Table 4.14: Float and Sink Results of Sample no.10

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	1.63	5.13	1.63	5.13	98.37	36.7	0.815
1.4	2.57	8.62	4.2	7.27	95.8	37.46	2.915
1.5	12.42	16.45	16.62	14.13	83.38	40.59	10.41
1.6	10.68	28.46	27.3	19.74	72.7	42.37	21.96
1.7	18.55	35.33	45.85	26.04	54.15	44.78	36.58
1.8	24.63	42.22	70.48	31.7	29.52	46.9	58.17
>1.8	29.52	58.51	100	39.61	-	-	85.24

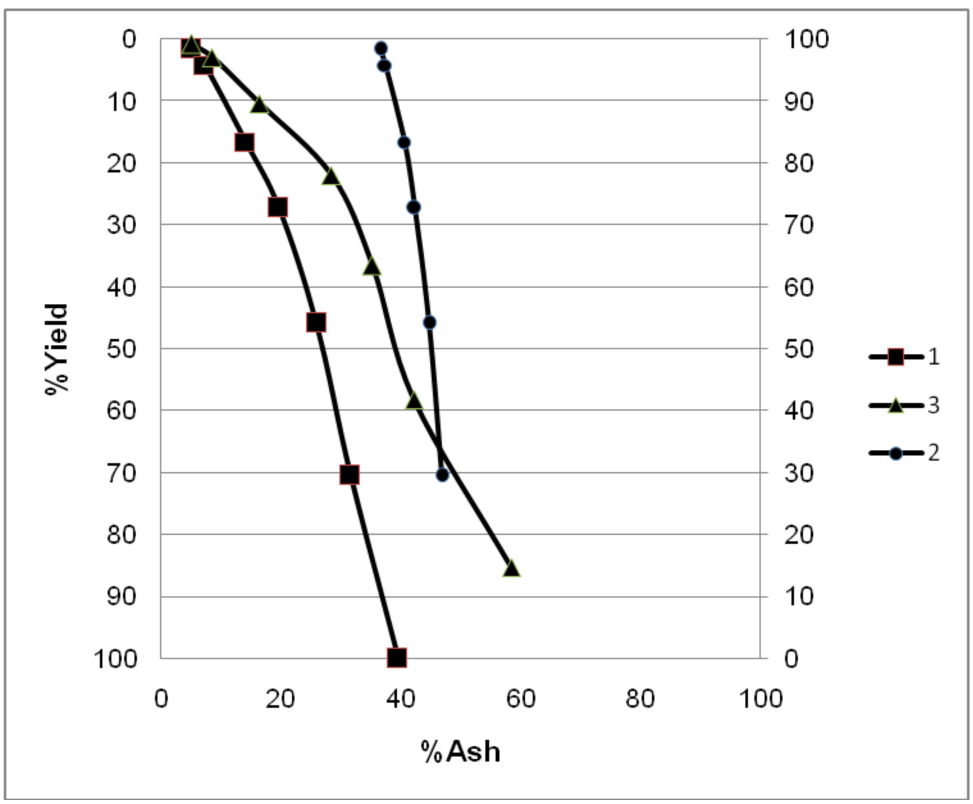

Figure 4.10: Washability Curves for Sample no.10

Table 4.15: Float and Sink Results of Sample no.11

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	6.35	9.52	6.35	9.52	93.65	29.36	3.18
1.4	26.25	15.63	32.6	14.44	67.3	34.76	19.48
1.5	21.99	23.94	54.59	18.27	45.4	39.92	43.59
1.6	22.78	33.56	77.37	22.77	22.63	46.32	65.98
1.7	7.34	40.82	84.71	24.33	15.29	48.98	81.04
1.8	8.21	48.62	92.92	26.48	7.08	49.36	88.82
>1.8	7.08	62.81	100	29.05	-	-	96.46

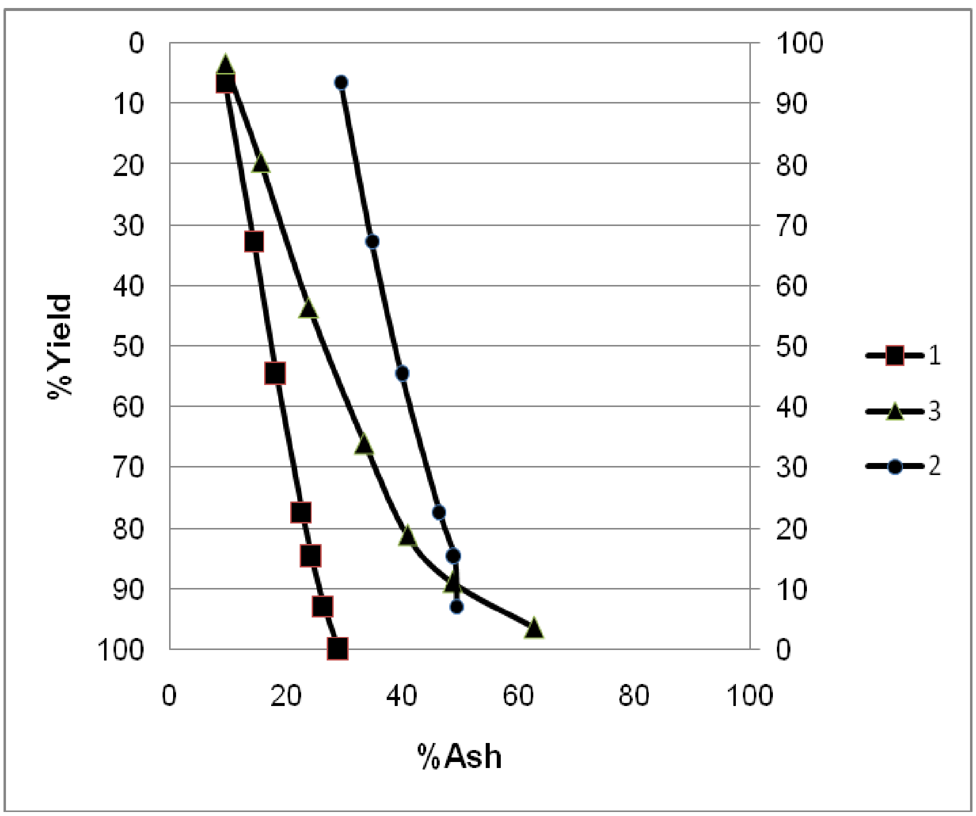

Figure 4.11: Washability Curves for Sample no.11

Table 4.16: Float and Sink Results of Sample no.12

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	7.62	10.91	7.62	10.91	92.38	39.8	3.81
1.4	9.76	18.77	17.38	15.32	82.62	42.29	12.5
1.5	25.33	28.58	42.71	23.19	57.29	48.34	30.05
1.6	28.96	42.37	71.67	30.94	28.33	54.45	57.19
1.7	12.67	51.29	84.34	33.99	15.66	57.04	78.01
1.8	5.34	58.88	89.68	35.48	10.32	59.55	87.01
>1.8	10.32	64.94	100	38.51	-	-	94.84

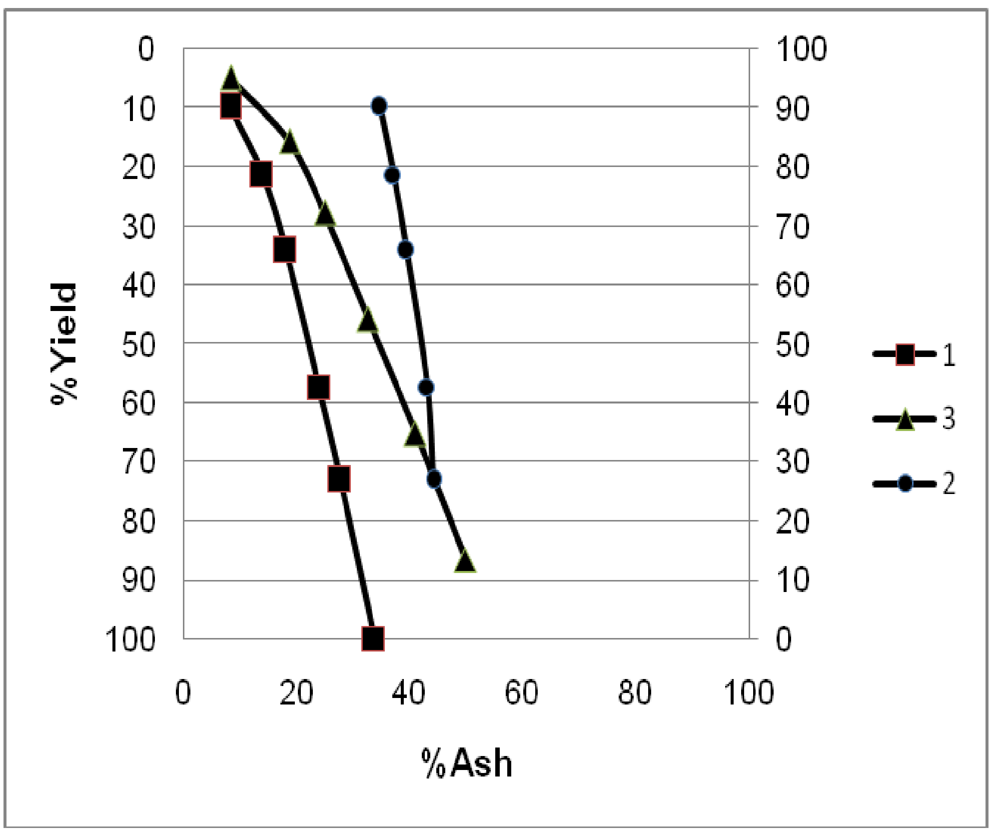

Figure 4.12: Washability Curves for Sample no.12

Table 4.17: Float and Sink Results of Sample no.13

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	1.56	6.33	1.56	6.33	98.44	52.72	0.78
1.4	3.98	15.84	5.54	13.16	94.46	54.28	3.55
1.5	11.54	29.83	17.08	24.42	82.92	57.68	11.31
1.6	21.61	43.62	38.69	35.15	61.31	62.63	27.89
1.7	12.54	55.77	51.23	40.19	48.77	64.41	44.96
1.8	25.22	64.43	76.45	48.19	23.55	67.33	63.84
>1.8	23.55	72.19	100	53.84	-	-	88.23

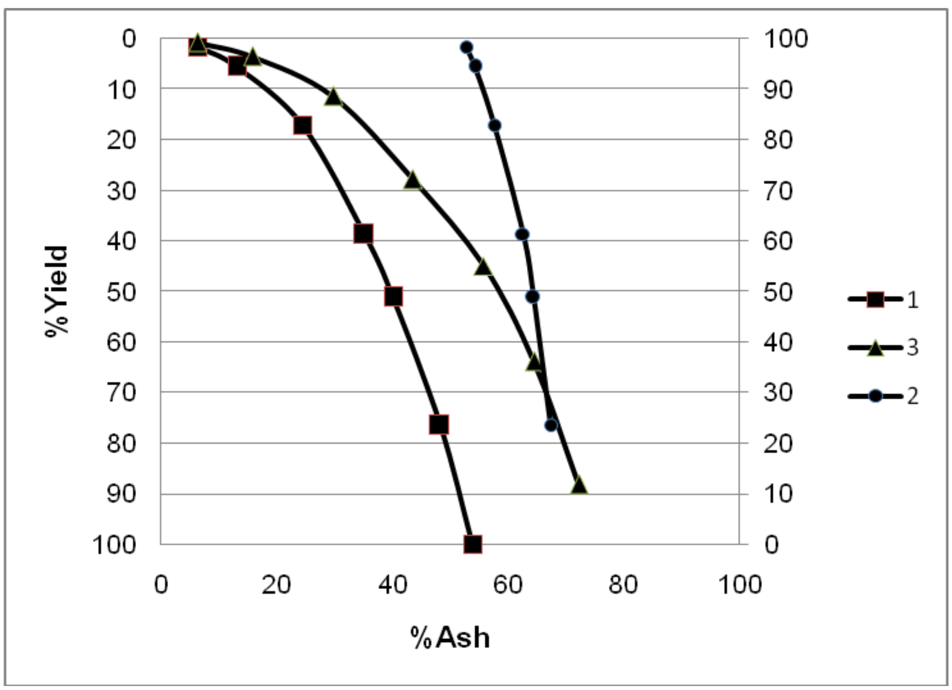

Figure 4.13: Washability Curves for Sample no.13

Table 4.18: Float and Sink Results of Sample no.14

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	1.34	5.62	1.34	5.62	98.66	44.54	0.67
1.4	5.32	11.45	6.66	10.28	93.34	46.43	4
1.5	8.68	24.22	15.34	18.17	84.66	48.7	11
1.6	12.39	33.67	27.73	25.1	72.27	51.28	21.54
1.7	8.67	42.58	36.4	29.26	63.6	52.47	32.07
1.8	28.95	49.68	65.35	38.31	34.65	54.79	50.88
>1.8	34.65	58.49	100	45.29	-	-	82.68

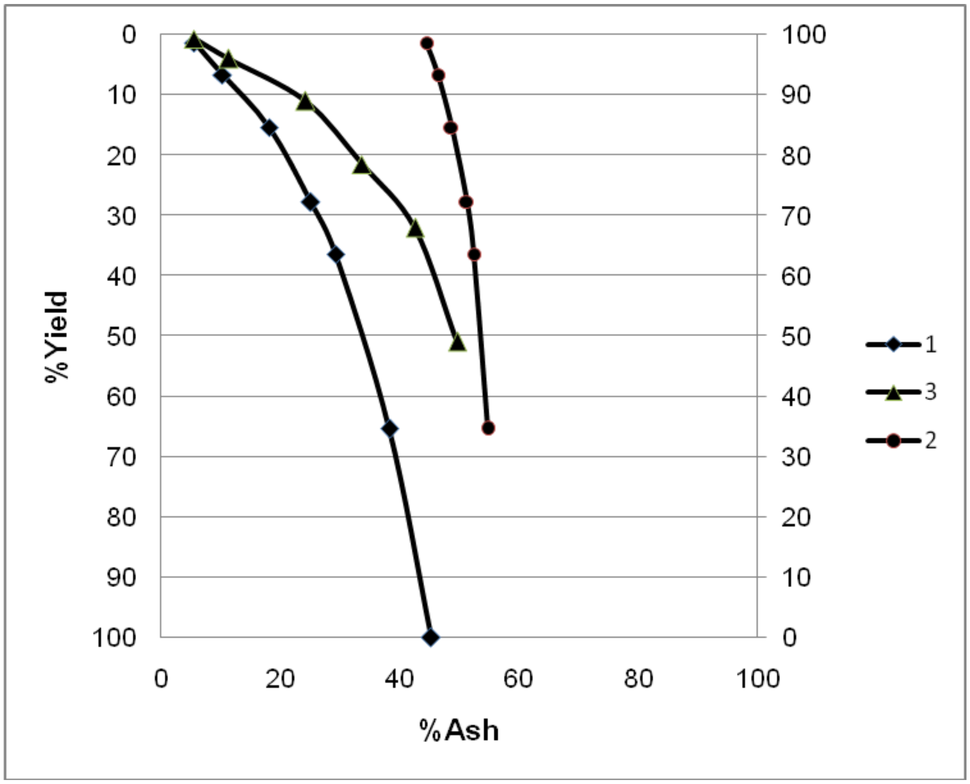

Figure 4.14: Washability Curves for Sample no.14

Table – 4.19: Float and Sink Results of Sample no.15

Specific gravity	Yield of each fraction (in %)	Ash of each fraction (in %)	Yield of total floats (in %)	Ash of total floats (in %)	Yield of total sinks (in %)	Ash of total sinks (in %)	Yield upto middle of fraction (CMF) (in %)
I	II	III	IV	V	VI	VII	VIII
1.3	10.55	7.42	10.55	7.42	89.45	36.49	5.28
1.4	5.63	15.7	16.18	10.3	83.82	37.89	13.37
1.5	28.92	25.68	45.1	20.16	54.9	44.31	30.64
1.6	25.66	35.98	70.76	25.9	29.24	51.62	57.93
1.7	6.45	47.44	77.21	27.7	22.79	52.8	73.98
1.8	11.56	54.33	88.77	31.17	11.23	53.42	82.99
>1.8	11.23	62.96	100	34.68	-	-	94.39

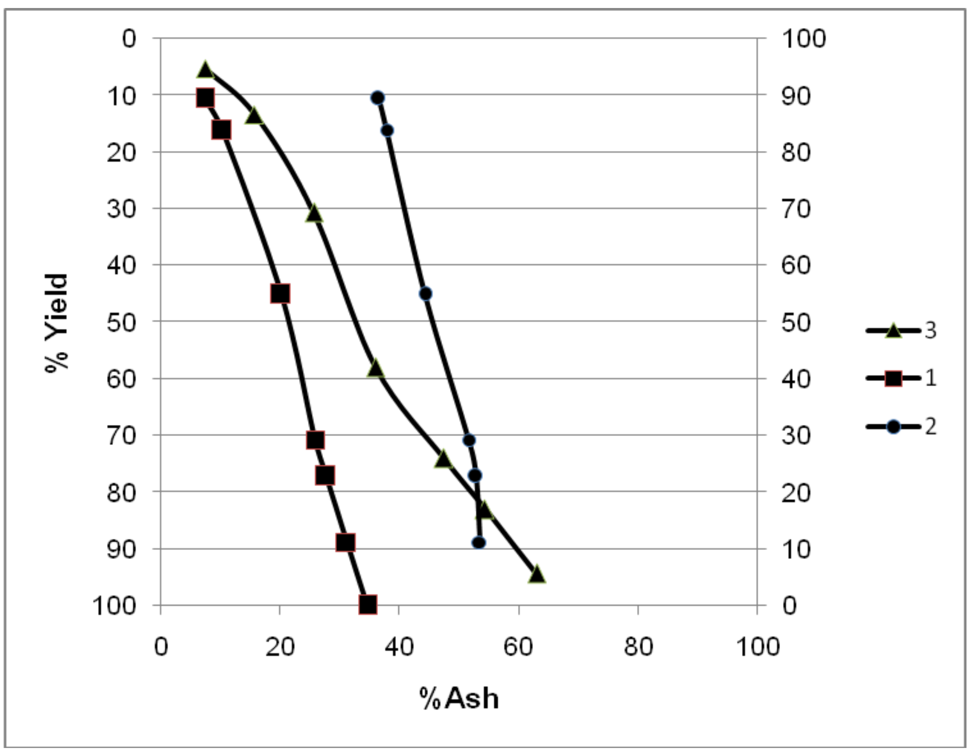

Figure 4.15: Washability Curves for Sample no.15

Chapter 5

DISCUSSION AND CONCLUSION

5. DISCUSSION AND CONCLUSION

To determine the quality of some Indian coals a number of experiments were conducted during the project work. The experiments that were conducted are proximate analysis, determination of hardgrove Grindability Index (HGI), determination of calorific value by using bomb calorimeter and washability studies by float and sink analysis.

As the sample collected were non–coking and so plastic properties were not determined. Also adequate facility to conduct the experiments required for ultimate analysis was not available so this test was also not carried out.

The proximate analysis of all the 15 samples which were carried out following the Indian Standard procedure. The percentages of moisture(M), volatile matter(VM) and ash content(A) of all the samples have been shown in figure 5.1. It may be observed from table 4.1 and figure 5.1 that the sample no.8 has the highest moisture content (13.15%) and sample no.13 has the lowest(2.4%). Generally the moisture values varied from 6%– 10%. From this we conclude that sample no.8 will take more time for heating and will have lower calorific value. Also sample no.8 will be consumed more for a certain heating purpose than other coals.

It was also found that sample no. 5 and 7 have the highest volatile matter content (33.82% and 33.96%) respectively, where as sample no .13 has the lowest volatile matter content (23.27%). It has been observed in the past that coals with high volatile-matter content ignite easily and are highly reactive in combustion applications. With increase in volatile matter content of coal there is a decrease in the calorific value of coal. Sample no. 5 and 7 could be utilized for combustion applications very conveniently, but they may need a larger furnace volume for the same. These types of coals may even consider for liquefaction and gasification purposes since the yield of tar and gases for such coals will be higher.

The ash content of the samples varied to a large extent form 8.845 for sample no. 7 to 52% for sample no. 13. Majority of the samples have ash content in excess of 25% and will create problems during combustion. These may give rise to formation of clinkers in the furnaces hindering the reactions. These samples when burnt will give rise to environmental pollution to a significant extent. It is therefore essential that these coal samples be washed before being utilized by the industries.

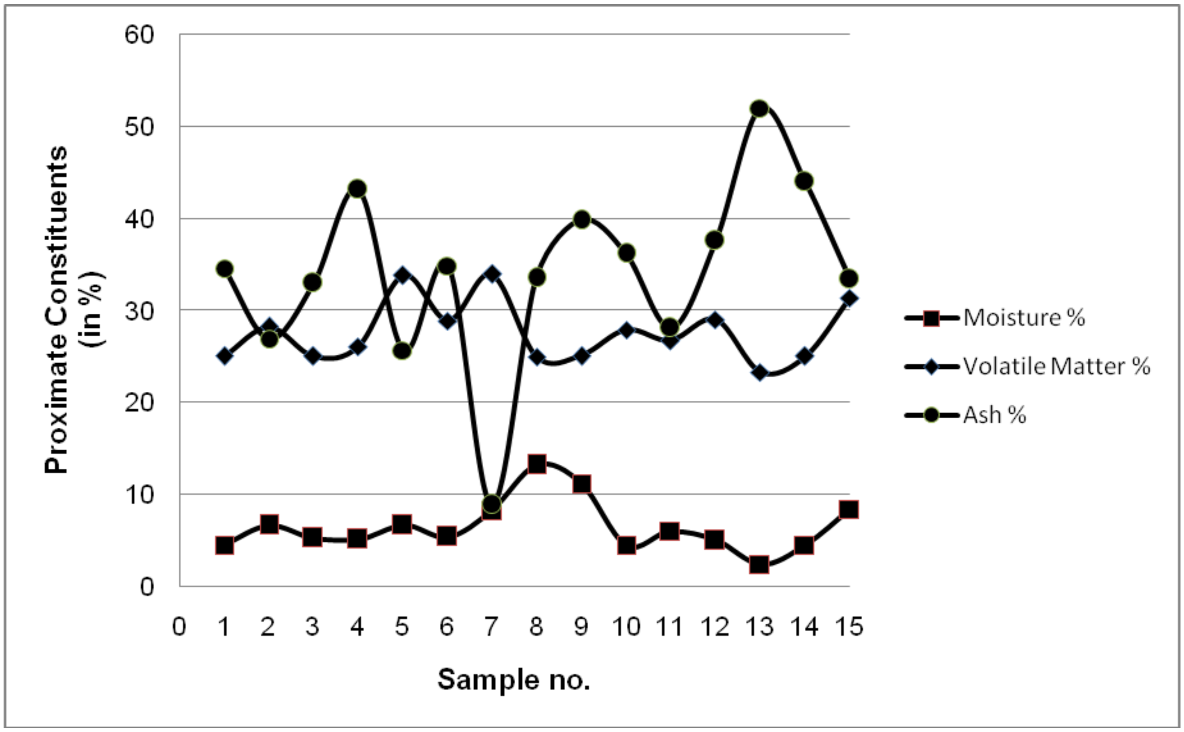

Figure 5.1: Plot of Sample nos. Vs Constituents of Proximate Analysis

The fixed carbon content which has a direct relation with the calorific value varied between 22.6% (sample no. 13) and 53.16% (sample no. 7). It could be observed from table 4.1 that the fixed carbon content of 14 samples are below 40% and it is expected that their calorific value will be low. These samples could be utilized in thermal power plants and other small industries for combustion processes.

The grindibility index of coal gives an idea about the strength of coal. It's a measure to know as to how easy or difficult it is to grind a particular coal. The grindability index of the samples varied between 48.69 (sample no 8) and 76.65 (sample nos. 6 and 14). It could be seen from table 4.2 that only a few samples are easy to grind and the rest are very difficult. This index will help in deciding the size of the crushers and grinders that would be required in coal preparation plants.

The calorific value was found out using bomb calorimeter. It was found that sample no.10 and 11 have the highest calorific values which are also consistent with the fact that they fixed carbon content in the higher range and low ash content. Sample nos. 13 & 14 were found to have the low calorific values, they also have the ash% in the higher range. It could be inferred that sample nos. 10, 11 are better for fuel purposes than rest of the samples.

Washability studies indicate at which specific gravity coal should be washed and which coal is easier and which one is the difficult among to get washed. Table 5.1 presents the summarized results of yield and ash percentages that will be obtained at different specific gravity cut off of washed coals.

Table 5.1: Yield and Ash Percentage of Coal Samples at different Specific Gravities

Specific gravity	Sample no.1		Sample no.2		Sample no.3		Sample no.4		Sample no.5	
	Yield%	Ash%	Yield%	Ash%	Yield%	Ash%	Yield%	Ash%	Yield%	Ash%
1.4	4.16	6.81	31.84	13.68	15.18	8.42	6.72	10.56	30.67	13.67
1.5	16.58	14.03	54.5	17.4	27.4	12.64	15.64	18.34	53.33	18.32
1.6	27.26	19.68	74.08	20.82	40.82	18.12	27.78	25.04	76.51	22.73
1.7	46.04	25.39	84.42	23.35	65.25	24.12	36.14	29.09	83.47	24.21
1.8	68.68	30.46	96.9	26.9	78.8	27.68	64.7	37.77	91.95	26.55

Specific gravity	Sample no.6		Sample no.7		Sample no.8		Sample no.9		Sample no.10	
	Yield%	Ash%	Yield%	Ash%	Yield%	Ash%	Yield%	Ash%	Yield%	Ash%
1.4	15.51	9.48	49.59	6.54	15.83	10.21	7.43	9.33	4.2	7.27
1.5	45.19	19.23	79.74	8.12	41.16	20.84	17.54	15.12	16.62	14.13
1.6	68.96	25.62	98.04	10.06	70.08	28.12	27.22	20.21	27.3	19.74
1.7	77.94	28.04	-	-	82.74	31.03	49.79	29.46	45.85	26.04
1.8	87.56	30.84	-	-	87.07	32.28	77.61	37.46	70.48	31.7

Specific gravity	Sample no.11		Sample no.12		Sample no.13		Sample no.14		Sample no.15	
	Yield%	Ash%	Yield%	Ash%	Yield%	Ash%	Yield%	Ash%	Yield%	Ash%
1.4	32.6	14.44	17.38	15.32	5.54	13.16	6.66	10.28	16.18	10.3
1.5	54.59	18.27	42.71	23.19	17.08	24.42	15.34	18.17	45.1	20.16
1.6	77.37	22.77	71.67	30.94	38.69	35.15	27.73	25.1	70.76	25.9
1.7	84.71	24.33	84.34	33.99	51.23	40.19	36.4	29.26	77.21	27.7
1.8	92.92	26.48	89.68	35.48	76.45	48.19	65.35	38.31	88.77	31.17

It may be observed from table 5.1 that at low specific gravity cut off values the yield of clean coals is very poor even though the ash content is low. However, a high yield of recovery may be obtained for sample nos. 2, 5, 7, 8, 11, 12, and 15 at a cut off of 1.6 specific gravity with less than 25% of ash in the clean coals. It may also be noted that sample no. 7 has the highest yield of clean coals at specific graviy cut off values of 1.5 and 1.6 with less than 10.06% of ash and less amount of near gravity material and can be cleaned without much difficulty. For the rest of the samples the washability problem of the coal samples varies from very difficult to formidable.

CONCLUSION

It could be observed from this study that the coal samples collected for the study contain low to medium quantity of moisture, medium to high amount of volatile matter and high amount of ash in general. The grindability index of majority of the coal samples being low they are vey difficult to grind as well. The calorific values of the coals vary between 3345 kcal to 4703 kcal. A few of these coals could be washed easily, but for majority of the samples the washing problem varies between very difficult to formidable. Thus all these coals could be used ion thermal power plants and in other small scale industries for combustion purposes. However, proper pollution control arrangements are required to made since these coals are expected to give rise to huge amount of noxious pollutants during burning, because the ash content of the coals are very high.

Chapter 6

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6. REFERENCES

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