ENVIRONMENTAL GEOSCIENCES

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Lecture-51

Fossils Fuels - Coal

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are discussing the Module ten. Module ten consists of Fossils, Fuels, Conservation of Non-Renewable Resources. We have discussed lecture one, today we will discuss the lecture two that is fossil fuels and within that we will discuss in detail about the coal. In this second lecture, the important concepts will be covered like introduction to coal, composition of coal, origin of coal, formation of coal, types of coal, bands of coal, some properties of coal. structure of coal, mode of occurrence, distribution of Indian coal, uses of coal, estimated reserves of coal in India and other solid fuels.

Coal is one of the principal mineral fuels. Coal is the most abundant fossil fuel. It is relatively evenly distributed worldwide. Its global reserves are enormous and far exceed those of oil or natural gas. Coal is considered to have been formed from accumulated vegetable matter that was buried and subjected under high pressure and temperature to anaerobic and aerobic decay over the geological times.

The decomposition of the organic matter proceeded at different rates depending on the raw materials and local conditions and their changes over time. Coal is not a simple, homogeneous, carbonaceous material but a complex substance with a varying chemical composition. The energy and combustion characteristics of coal depend significantly on its composition, which in turn depends on many factors that include its source of vegetation, the associated inorganic matter and the history of the sequence of events and processes that led to its eventual formation. Generally coal burns as either caking or free-burning solid fuels. Caking coals tend to diffuse when heated, forming a semi-coke pasty material that is non-porous, whereas free-burning coals tend to crumble when heated.

Now we will discuss the composition of coal. Chemically, coals are composed of organic and mineral matter. Their organic mass consists of carbon, that is sixty to ninety percent, slight hydrogen that is one to twelve percent, oxygen that is two to twenty percent,

nitrogen one to three percent and slight amounts of sulphur and phosphorus. The proportion of these elements progressively varies with the advance of coalification processes starting from plant material with the carbon content steeply increasing and hydrogen, oxygen contents decreasing. The chemical composition of coal is determined either by the proximate analysis or by the ultimate analysis.

A general evaluation of the quality of coal can be made on the basis of the data furnished by the proximate analysis regarding moisture content, volatile matter content, ash percentage, fixed carbon, heating value of coal, etc. Fixed carbon is the value obtained by subtracting the sum of percentages of moisture, volatile matter and ash from hundred. That is, fixed carbon percentage is equal to hundred minus moisture percentage plus percentage of volatile plus ash percentage. Fuel ratio is a ratio between fixed carbon and volatile content. The heating value or calorific value of coal represents the amount of heat liberated by the complete combustion of a unit weight of coal.

The value is represented in two standards of unit as British thermal unit and calorie. Here is one example. A sample of coal has the following composition. That is moisture content is twelve percent. Volatile matter is twenty-eight percent.

Ash content is equal to fifteen percent. Now question is calculate the fixed carbon percentage and fuel ratio in the coal sample. Now given moisture percentage is equal to twelve percent. Volatile matter percentage is twenty-eight percent and ash content percentage is fifteen percent. By applying in the formula which I have discussed in the previous slide, fixed carbon percentage is generally we are finding by just subtracting the summation of moisture percentage, percentage of volatile and ash percentage in hundred.

So we are getting just by putting the value of all these, we are getting fourty-five percent of the fixed carbon percentage in the coal sample. Now, regarding the fuel ratio. Fuel ratio, we have read that it is the fixed carbon divided by volatile content. So, just putting the value because fourty-five percent we get from here, fixed carbon. So, it is coming to, fuel ratio is coming to one point six zero seven.

Now, origin of coal. It has been established that coal had its origin in the accumulation of vegetal matter, which has been subjected to a variety of geological processes, bringing about marked changes in the physical and chemical composition. The changes are revealed by the gradual darkening of colour, increase in compactness, hardness and carbon content, and decrease in moisture and volatiles. Two views have been advanced to

explain the origin of coal. The views are, first is the growth in situ theory and second is the drift theory.

Now growth in situ theory, this theory states that coal vegetation was fossilized practically on the site of the growth, either due to the tectonic movement or due to some other reasons. Now what are the evidences? Evidences in support of this theory are that a vast amount of plant material is accumulated in situ in the present day swamps. Second, many fossilized tree trunks are found in erect positions with their roots firmly fixed in the underclays that lie beneath the coal seams. And third support is a comparatively pure state of coal seams indicates that the material accumulated without getting mixed with adventitious material and had not been transported along with the sediments.

Now second theory is the drift theory. The drift theory is, however, strongly held by some geologists, which states that the coal seams have been formed as a result of drifting and subsequent accumulation of plant bodies away from their place of growth. Now, again, the evidences in support, the evidences in support of this theory are no underclays representing the soil at the root are associated with the coal. Second, stems with the roots in upright positions are not found. Third, beds of coal are observed to branch out, which is the characteristic only of drift matter.

Coal seams occur in association with sedimentary rocks and itself behave like a stratified sedimentary rock. Presence of channel sands indicate crisscross movement of the water through swamps. Now formation of coal. The process of formation of coal is complex and involves both bacteriological and physical agencies. According to A. M. Bateman, the following are essential for the formation of coal.

First is the source material. Plants and trees are the chief source material. Second is the places and conditions of accumulation. The extensive distribution of individual coal seams implies swamp accumulation on broad delta and coastal plain areas, on broad interior basins, lowlands that have been base-levelled, etc. Thus, the coal-bearing horizon should be a basin-like structure where the area should be swampy naturally.

Third is the climate condition. The favorable climatic conditions are mild temperate to subtropical climate and with moderate to heavy rainfall well distributed throughout the year. Now stages of formation of coal. There are two stages of formation of coal. First is the biochemical stage and the process is known as humification or peat forming stage.

And second is the geochemical stage where the process of coalification takes place. Biochemical stage, humification processes, the changes brought about in the plant debris during this process are due to the decay and decomposition of the substances like resins, lignins, proteins, cellulose, etc. present in plants. These changes are brought about by the activity of bacteria and other microorganisms which ideally thrive in swampy conditions. This process is also called fermentation and the result is the formation of a porous, fibrous and friable mass which is called as peat. A necessary step in the process of humification is that the decay be arrested before complete destruction ensues so that the residue can accumulate.

This is accomplished by means of decay-promoting bacteria that makes the stagnant water toxic, which prevents further decay of vegetable tissues and permits their preserve and accumulation. Now second process is the coalification process. Plant materials are first converted to peat that has high moisture content and a relatively low heating value. Peat once formed under the prevailing conditions at depth in the earth crust and due to various geological factors is transformed through various stages to coal. Thus peat is first converted to lignite, lignite to bituminous coal and bituminous coal into anthracite.

This series of feet, lignite, bituminous, anthracite is called coalification. The rank of the coal increases at a place with depth. Here you can see in the diagram also the coal formation, that is the coalification processes. At the bottom you can see the coal seam, above it the shale, then the sandstones, then again the lignite, Again, shale we are getting, then sandstone, then consolidated peat, then siltstone.

Then at the top, if you will see, the peat is there and peat above it is the decaying vegetation. So this is the, at the bottom we are getting the coal seam at depth. Now types of coal. There are four major coal types or ranks. Rank refers to steps in a slow natural process called coalification during which buried plant matter changes into an ever denser, drier, more carbon rich and harder material.

The four ranks are anthracite, bituminous, sub-bituminous, lignite. Now first, anthracite, it is the highest rank of coal. It is hard, brittle and black, lustrous coal, often referred to as a hard coal. It contains a high percentage of fixed carbon and a low percentage of volatile matter resulting in high calorific value and low ash content. Bituminous coal is a middle-rank coal between sub-bituminous and anthracite.

It usually has a high heating value and is used in electricity generation and steel making. It is blocky and appears shiny and smooth when you first see it. But if look closer, it has

thin, alternating, shiny and dull layers. The diagram is the schematic of composition of coal. We have learned that the anthracite is the good quality.

Anthracite, then bituminous, then sub-bituminous, then lignite. So as you can see the combustion rate also in the y-axis and time in the x-axis, the composition of different types of coal. Third category is the sub-bituminous. Sub-bituminous coal is black in color and is mainly dull. Dull means not shiny and shows some woody materials.

Sub-bituminous coal has low to moderate heating values and is mainly used in electricity generation. Then the fourth category is the lignite. Lignite coal which is also called as brown coal. It is the lowest grade coal with the least concentration of carbon which are formed from the peat. Lignite has a low heating value and a high moisture content and is mainly used in electricity generation. Now the different bands within the coal.

Humic coals are banded coals. They are the most abundant type of coal. The bands of coal that comprise a humic coal are divided into four lithotypes based on their general appearance. The bands are vitrain, clarain, durain and fusain. Vitrain band is a bright, shiny, black bands of coal, usually brittle and cut by fissures.

Vitrain tends to break into small, blocky pieces. It is the shiniest of the four lithotypes. Then the clarain, semi-bright, black layers composed of very finely interlayered vitrain, durain, and sometimes fusain. It is brighter than durian, but not as bright as vitrain. Durian, it is dull, black to gray layers with a rough texture.

Bands are not as bright as clarain or vitrain and have less fissures than vitrain. When broken, durian bands tend to break into irregular lumps rather than small blocks. And fusain, it is dull, black to gray-black bands with an almost silky luster. They may have a fine fibrous appearance. Fusain is soft and friable like charcoal.

Fusain bands are often responsible for the dirty hands one gets from holding a coal sample. Now, the properties of coal. Proximate analysis is the composition by mass of the major constituents of coal. According to industrial standard, it is as follows. Inherent moisture in percentage.

Inherent moisture is the concentration of moisture in the coal as received. Increased moisture reduces the heating value of coal proportionally. Volatile matter, again it is in percent. Volatile matter is the mass loss from a coal sample when heated in an inert atmosphere. Volatile consists of vapors of various hydrocarbons, tar, and so on.

Coals of high volatile content, that is low-rank bituminous, are easy to ignite, burnt quickly with a long orange flame and require an adequate supply of secondary air to ensure complete combustion of the released volatiles within a relatively short time. On the other hand, coals of low volatile content that is anthracite are difficult to ignite and slow to burn. They produce a short flame and require an ample supply of primary air through the coal bed. Now, ash in percentage. Ash in coal consists mainly of mineral matter such as oxides of silicon, iron, aluminium and calcium.

It is the leftover material following the heating of a known coal sample in a stream of air heated to high temperature that is seven hundred degree centigrade to seven fifty degree centigrade. The presence of ash reduces the heating value and the caking of coal and adds to the difficulties of effective utilization of coal. Following burning, relatively very large quantities of leftover ash are produced, which must be removed. Fixed carbon in percent. Fixed carbon is a term given to the remaining mass after subtracting the moisture, volatile and ash contents of coal.

Combustible, again in percent, a combustible is usually reckoned on the basis of volatiles and fixed carbon components. Rank of coal, this is a way of classifying the quality of coal by comparing the fixed mass of carbon to the volatiles of the fuel. On this basis, anthracite has a higher rank than bituminous coals. Ultimate analysis, this is the percentage on a mass basis of the various individual elements and ash making up dry coal. Heating value, the heating value of coal can be quoted in a variety of ways such as a higher heating value when the water in the products has been considered and its energy counted, and a lower heating value when all the water in the products remains as vapor and is considered not to have been removed from the products of the combustion.

There are also a number of other properties associated with coal such as caking and swelling tendency, ash fusion temperature, size of pellets and ease of grindability. Here in the table, you can see the composition on a mass basis of different classes of coal. You can see in peat, the moisture is seventy to ninety percent. Carbon content is fourty-five to sixty percent. Whereas in lignite, it has in, carbon content has increased to sixty to seventy-five percent. Bituminous, it has increased to seventy-five to ninety-two percent. And anthracites, it is up to ninety-two to ninety-five percent.

So, in this way, we can have the idea of the moisture percent, carbon percent, hydrogen percent, oxygen percent, volatile percent and higher heating value of the different types of coal that is peat, lignite, bituminous and anthracites. Structure of coal. The structure of

coal is extremely complex and depends on the origin, history, age and rank of the coal. The molecular and conformational structures of coal are studied to determine its reactivity during combustion, pyrolysis, and liquefaction processes. Structures were derived using data obtained from various analyses, including coal atomic composition, analysis of products from chemical reactions, coal liquefaction, and pyrolysis.

Mode of occurrence, coal occurs as a sedimentary rock in association with sandstone, carbonaceous seal and occasionally fire clay in a regular succession and with repetitions. Tertiary coal in certain cases found to occur as in-situ deposits. Gondwana coal occurs as drifted deposits. Igneous intrusion in the form of dykes and sills are present in the coal seams. Generally, the intrusives are of mica peridotite, lamprophyre and basic dolerites.

Distribution of Indian Coal. The coals of India belong to two principal geological periods. The first is the lower Gondwana coals of Permian age and second is the Tertiary coals of Eocene to Miocene age. The greatest period of coal formation in India is the Permian. The important coal-bearing formations are collectively known as Damudas and belong to the lower Gondwana system. The lower Gondwana coal account for more than ninety-eight percent of the annual production of coal, which are generally of bituminous rank, whereas in tertiary coal fields lignite predominates.

Now the Gondwana coal. The Gondwana coals are largely confined to the river valleys like the Damodar, Mahanadi, Godavari etc. The workable coal seams are confined to the Damuda group of the lower Gondwana wherein they occur in two main horizons. The first is the Barakar measures of lower Permian age and second is the Ranigal measures of the upper Permian age. The coal seams of the Barakar measures are more important because they are of better quality and occur in all the fields whereas coal seams of Ranigan measures occur principally in the Ranigan coal field only.

Barakar coals of the Jharia coal field possess low moisture, low volatile, high fixed carbon, high ash, low sulphur and low phosphorus content. In comparison to this, the Raniganj coals contain high moisture, high volatiles, medium fixed carbon, medium ash, low sulphur and low phosphorus contents. While the Barakar coals are good coking and steam coals, the Raniganj coals are poorly coking but excellent steam coals. Amongst the important lower Gondwana coal fields of India, The important ones are Raniganj Coalfields of West Bengal, the Jharia, Giridih and Bukaro Coalfields of Jharkhand, the Talchir Coalfield of Orissa, the Umaria, Sohagpur, Mohapani, Korba and Pench Valley Coalfields of Madhya Pradesh and the Singreni Coalfields of Hyderabad.

Now, regarding Tertiary Coals. They principally occur in Assam, in the Himalayan foothills of Kashmir, and in Rajasthan, that is Palna in Bikaner, in Eocene Strata. Besides, lignite deposits are found to occur in South Arcot district of Tamil Nadu, in Kutch of Gujarat, and also in the state of Kerala. The Neyveli lignite field of Tamil Nadu, which is of Miocene age, is the largest lignite deposit of South India. In India, coals of super bituminous to anthracite variety occur in the Eocene formation of Kashmir along the Himalayan foothills as well as in the lower Gondwana strata in the eastern Himalayan region.

Now, uses of coal. Coal is a primary source of heat and power, that is thermal power. It is also used in the production of water gas, in metallurgical operations for the purpose of extraction of metals like iron, zinc, etc. Gasification of coal which leads to the production of coal, gas, tar, coke, etc. Different types of varnish and germicides are also produced from coals.

Estimated reserves of coal in India India has rich deposits of coal in the world. Total estimated reserves of coal as on one four two zero two two were three sixty one point four one billion tons, an addition of nine point two nine billion tons over the corresponding period of previous year. The top three states with highest coal reserves in India are Odisha, Jharkhand, Chhattisgarh, which account for approximately sixty-nine percent of the total coal reserves in the country. Out of the total reserves in the country, proven reserves that is those available for extraction in terms of that is economically viability, feasibility study and geologically exploration level account for almost fifty-two percent of the total.

In the side figure, you can see estimated reserves of coal in India as on first of April two zero two two. Details about the indicated, inferred and proved reserves. Other solid fuels. Peat. Peat is a soft organic material of much recent age in comparison with coal.

Peat contains a very high concentration of water and consists of partly decayed vegetable matter of woody plants, reeds and mosses that accumulated in anaerobic water saturated conditions and were subjected to bacterial actions. Peat is used in horticulture and when dried through its smoky burning for the production of thermal energy. It may be compressed at high temperatures to form briquettes that are used occasionally as a domestic fuel. Peat has a low heating value even when dried compared to the other conventional fossil fuels. Often peat fields emit in significant quantities the greenhouse

gas methane, which is much more potent than carbon dioxide in its contribution to global warming.

Wood Wood as a fuel still holds an important place not only in the developing world but also in the developed world. Leftovers from the production, leftovers from the production of lumber, pulp and paper are often used to produce biogases, process steam and heat. The various types of wood comprise broadly three types of the material that is the largest fraction by mass of various types of wood is cellulose. Wood combustion, similar to the combustion of other solids, takes place in consecutive, initially endothermic stages that begin with preheating, followed by drying near the combustion surface, volatilization, pyrolysis, and then exothermic oxidation.

The more moisture present, the more energy is required to drive the water out and initiate combustion. Charcoal and coke are fuels manufactured or processed from naturally occurring solid fuels and raw materials. When carbonaceous materials are burned in the closed environment of a retort with insufficient air, the volatiles are driven off and a residue of coke or charcoal is left. The term coke is reserved for residues from coal and petroleum products, whereas charcoal comes from a wide variety of woody, agriculture, and animal products, for example, wood, coconut shells, and bones. And the next is the biomass.

Biomass is an important source of sustainable energy. It includes industrial, agriculture, livestock and forestry residues. Some are grown specifically for the conversion into energy resources. Most biofuels have the potential to produce energy that is on the occasion greater than the energy required for their production. Biomass can be burned directly or converted into solids, that is charcoal liquids, that is methyl alcohol, also known as wood alcohol, or gaseous fuels, that is biogases, through the process of gasification, liquefaction, fermentation, or bacterial digestion.

Bacterial degradation of biomaterial produces mainly methane in association with carbon dioxide. Now let us summarize the lecture. We have discussed first the introduction about coal. Coal is the most abundant fossil fuel which is formed from accumulated vegetable matter that was buried and subjected under high pressure and temperature to anaerobic and aerobic decay over geological times. Next, we have discussed the composition of coal.

The coal consists of carbon sixty to ninety percent, slight hydrogen that is one to twelve percent, oxygen two to twenty percent, nitrogen one to three percent, and slight amounts

of sulphur and phosphorus. There are two important theories regarding the origin of coal. The first is the growth in situ theory and second is the drift theory. Next, we have discussed about the formation of coal. There are two different stages of formation of coal.

First is the biochemical stage. The process is known as humification or peat forming stage. And the second is the geochemical stage where the process of coalification takes place. Types of coal, the four different types of coal are there. First, the anthracite, second, bituminous, third, sub-bituminous, and fourth, the lignite.

Next, the bands, four different bands remain present within the coal. The bands of coal that comprise a humic coal are divided into four lithotypes based on their general appearance, that is, vitrain, clarain, durain, and fusain. And lastly, we have discussed about the distribution of Indian coal. We have seen that two important geological periods are there in which we got the coal. The first is the lower Gondwana coals of Permian age and second is the tertiary coals of Eocene to Miocene age.

Thank you very much to all.