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COAL AND ITS COMBUSTION PRODUCTS: A GLOBAL PERSPECTIVE

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Abstract*- Coal is the primary source of energy for most of the countries in the world although the main use of coal is in the generation of electricity. Synthesis of liquid fuel from coal is becoming attractive which may relieve pressure on petroleum as the only source of automobile. A major concern in the use of coal is the emission of various pollutants including gases that cause acid rain and CO_2 emission responsible for global warming. The paper discusses on the coal, its classification, various uses and also the coal combustion products (CCPs) on global perspectives. The use of CCPs in construction reduces the need for quarried raw materials, manufactured aggregate, Portland cement, replacement of these virgin and manufactured materials with CCPs helps to reduce emission associated with their manufacturing and processing. It is estimated that there are over 850 Giga Tones of proven coal reserves worldwide which is enough to last more than 130 years at current rate of productivity. According to ACCA approximately 129 Million tons of CCPs has been generated in the USA in 2002 of which approximately 45 million tons (35%) were used in cement, concrete and in various other application.*

Keywords: Bottom ash, Coal, Coal combustion product, Coal mine, Fly ash.

1. INTRODUCTION

Coal is the primary source of energy for most of the countries in the world. Although the main use of coal is in the generation of electricity, recently synthesis of liquid fuel from coal is becoming attractive, although coal liquefaction is a very old and well known process that was developed just after World War 1. This may relieve pressure on petroleum as the only source of automobile fuel. However, a major concern in the use of coal is emissions of various pollutants including gases that cause acid rain and CO_2 emissions - a major contributor to global warming. Two approaches are pursued to reduce emissions from coal power plants. Most of the recent coal power plants are designed to produce supercritical steam, increasing the efficiency to about 50%. Another approach is to develop zero emission coal power plants. In 2011, global coal trade amounted to just over 1.142 billion tonnes or 15% of world coal production of 7.2 billion tonnes. Coal is traded all over the world, with coal shipped huge distances by sea to reach markets. Seaborne trade in steam coal has increased on average by about 7% and seaborne coking coal trade has increased by 1.6% each year over the past 20 years. World Coal Association (2011) reports lignite is mainly used in the vicinity of deposits. Coal from mines with low production costs and favorable locations near to seaports can be delivered competitively to overseas consumers.

Globally, 86% of coal used in thermal generation is currently black coal with 14% of brown coal/lignite making up the balance. The vast majority of this coal is used for power generation, largely by pulverized coal combustion. CCP utilization can be dated from the advent of widespread pulverized coal combustion for electricity generation in the 1920s when large amounts of CCPs began to become available. The first published use of fly ash in concrete was for sulfate resistant concretes exposed to seawater.

Two main theories have been suggested by scientists on the origin of coal or how coal is formed [1]. According to the first theory, coal formed in situ, where the vegetation grew and fell, and such a deposit is said to be autochthonous in origin. The starting constituents of coal are believed to be plant debris, trees, and bark that accumulated and settled in swamps. Composition of coals differs throughout the world due to the kinds of plant materials involved in the formation (type of coal), in the degree of metamorphism or coalification (rank of coal), and in the type of impurities included (grade of coal). However, there is a great controversy on the bearing of plant constituents, particularly cellulose and lignin, on coal formation.

The unconsolidated accumulation of plant remains is called peat. The beginning of most coal deposits started with thick peat bogs where the water was nearly stagnant and plant debris accumulated. The plant debris converted into peat by microbiological action. Over the years, these layers of peat became covered with sediment and were subjected to heat and pressure from the subsidence of the swamps. The cycles of accumulation and sediment deposition continued and were followed by digenetic (i.e., biological) and tectonic (i.e., geological) actions and, depending upon the extent of temperature, time, and forces exerted, formed the different ranks of coal observed today [2,3]. A number of researchers concluded that cellulose in plants was the main path towards the ultimate formation of coal [4,5]. Both the theories were reviewed by several groups and their applicability to various deposits around the world was discussed. However, it became certain from these reviews that one single theory could not be applied to explain all the deposits [6,7].

A metamorphic process, called coalification as shown in **Fig.1**, eventually formed the coal. The metamorphic process is thought to have occurred in several stages and the factors assumed to affect the content, makeup, quality, and rank of the coal are (i) Temperature, (ii) Pressure, (iii) Time, (iv) Layering process, (v) Fresh water/sea water, (vi) Swamp acidity, (vii) Types of plant debris, (viii) Types of sediment cover. Plant materials are first converted to peat that has high moisture content and a relatively low heating value. However, as the process of coalification continues under greater pressure and temperature, peat starts to lose moisture and other types of coal formed. The second theory stipulates that coal formed through the accumulation of vegetal matter that has been transported by water to another location [8,9]. According to this theory (i.e., allochthonous origin), the fragments of plants were carried away by streams and deposited on the bottom of the sea or in lakes where they build up strata, which later became compressed into coal. Major coal deposits were formed in every geological period since the Upper Carboniferous Period, 350-270 million years ago.

2.CLASSIFICATION

Coal is generally divided into two main categories: Anthracite (or Hard Coal) and Bituminous (or Soft Coal). The classification is mainly based on the carbon content and moisture content of the coal. As the coalification process continues the rank of the coal increases. The rank of coal is defined as the degree of changes (metamorphism) that occurs as a coal matures from peat to anthracite. The coal may be classified in a number of ways as described below. There are a number of subdivisions within these categories too.

(a) By ash content: Low ash (<5%), High ash (>20%)

(b) Its structure: Anthracite (nearly pure carbon), Bituminous (more bound hydrogen), Sub-Bituminous (less bound hydrogen), Lignite.

(c) Heating values: Anthracite: 22-28 x 106 BTU/ton, Bituminous: 25 x 106 BTU/ton, Lignites: 12 x 106 BTU/ton.

(d) Sulfur content: Low (<1%), High (about 7%).

(e) Coke grade: Metallurgical coke (premier grade), Non metallurgical coke (low grade)

(f) Caking properties: Caking, Non-caking

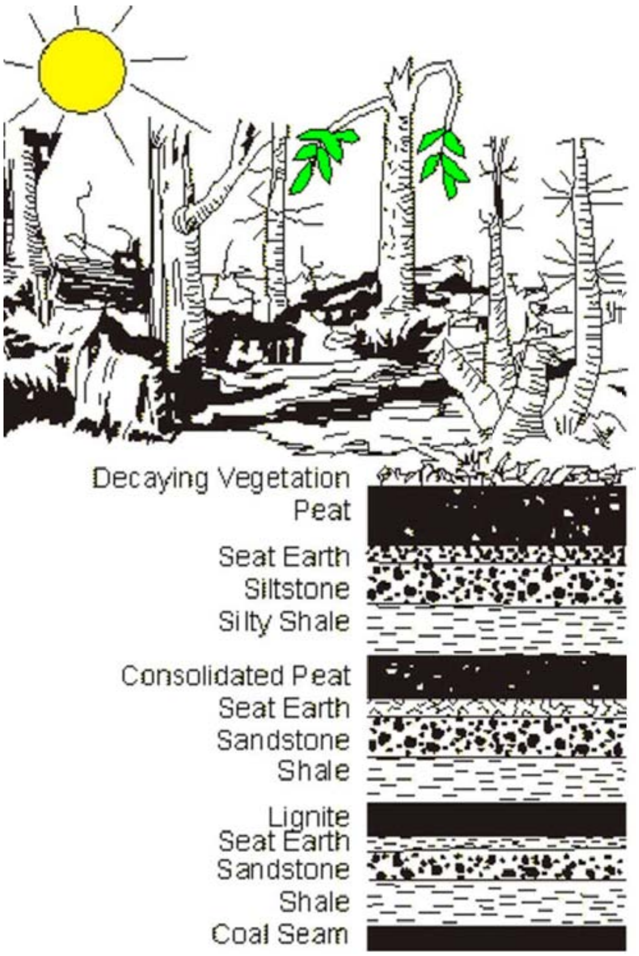

Fig.1: Coal formation process [10]

The American Society of Testing and Material (ASTM) have a standard classification of coals by ranks and is provided in their D388-84, which is given in **Table 1.** The four main constituents of coal are volatile matters, hydrogen, carbon, and oxygen. The percentage of these elements determines the heating value of coal rank. The C/H and (C+H)/O ratios are also important for determining combustion characteristics of coal. These values for different ranks of coal are shown in **Table 2.**

3. HISTORY OF COAL USE

Coal has a long and rich history. The commercial use of coal can be traced back to 1000 BC by China. However, there is evidence that coal has been used for heating by the cave men. Archeologists have also found evidence that the Romans in England used coal in the second and third centuries (100-200 AD). The first scientific reference to coal may have been made by the Greek philosopher and scientist Aristotle, who referred to a charcoal like rock. It was during the Industrial Revolution in the l8th and l9th centuries that demand for coal surged. The introduction of the steam engine by James Watt in 1769 was largely responsible for the growth in coal use.

Coal was discovered in the United States by explorers in 1673. However, the Hopi Indians used coal for cooking, heating and to bake the pottery during the 1300s. Commercial coal mines started operation around

1740s in Virginia. During the Civil War, weapons factories were beginning to use coal. By 1875, coke (which is made from coal) replaced charcoal as the primary fuel for iron blast furnaces to make steel. The use of coal for electricity generation started around the nineteenth century. The first practical coal-fired electricity generating station, developed by Thomas Edison, went into operation in New York City in 1882, supplying electricity for household lights. Coal was the primary source of energy until 1960s. The use of oil for transportation overtook coal as the largest source of primary energy in the 1960s.

However, coal still plays a vital role in the world's primary energy mix, providing 24.4% of global primary energy needs in 2003 and 40.1% of the world's electricity. The production and consumption of coal by various regions and some selected countries are given in **Table 3 and Table 4**.

Reserves

There are two internationally recognized methods for assessing world coal reserves. The first one is produced by the German Federal Institute for Geosciences and Natural Resources (BGR) and is used by the IEA as the main source of information about coal reserves.

Table 1: Classification of coal by rank according to ASTM standard D388-84

Class	Group	Fixed carbon limits (%) (dry mineral matter free basis)		Volatile matter limits (%) (dry, mineral matter free basis)		Calorific value limits (BTU/lb) (moist mineral matter free basis)		Agglomerating character
		Equal to or greater than	Less than	Greater than	Equal to or less than	Equal to or greater than	Less than	
I. Anthracite	1. Meta-anthracite	98	--	--	2	--	--	Non-agglomerating
	2. Anthracite	92	98	2	8	--	--	
	3. Semi-anthracite	86	92	8	14	--	--	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	--	--	Commonly agglomerating
	2. Medium volatile bituminous coal	69	78	22	31	14000	--	
	3. High volatile A bituminous coal	--	69	31	--	13000	14000	
	4. High volatile B bituminous coal	--	--	--	--	11500	13000	
	5. High volatile C bituminous coal	--	--	--	--	10500	11500	Agglomerating
III. Sub bitumi-nous	1. Subbituminous A coal	--	--	--	--	10500	11500	Non-agglomerating
	2. Subbituminous B coal	--	--	--	--	9500	10500	
	3. Subbituminous C coal	--	--	--	--	8300	9500	
IV. Lignite	1. Lignite A	--	--	--	--	6300	8300	Non-agglomerating
	1. Lignite A	--	--	--	--	--	6300	

Table 2: Classification profile chart.

Class	Group	Average analysis-moisture and ash free basis						
		Volatile matter (%)	Hydrogen (wt%)	Carbon (wt%)	Oxygen (wt%)	Heating value (kJ/kg)	C/H ratio	(C+H)/O ratio
Anthracite	Meta	1.8	2.0	94.4	2.0	34,425	46.0	50.8
	Anthracite	5.2	2.9	91.0	2.3	35,000	33.6	42.4
	Semi	9.9	3.9	91.0	2.8	35,725	23.4	31.3
Bituminous	Low-vol.	19.1	4.7	89.9	2.6	36,260	19.2	37.5
	Med-vol.	26.9	5.2	88.4	4.2	35,925	16.9	25.1
	High-vol. A	38.8	5.5	83.0	7.3	34,655	15.0	13.8
	High-vol. B	43.6	5.6	80.7	10.8	33,330	14.4	8.1
	High-vol. C	44.8	4.4	77.7	13.5	31,910	14.2	6.2
Sub-bituminous	Sub-bitu. A	44.7	5.3	76.0	16.4	30,680	14.3	5.0
	Sub-bitu. B	42.7	5.2	76.1	16.6	30,400	14.7	5.0
	Sub-bitu. C	44.2	5.1	73.9	19.2	29,050	14.6	4.2
Lignite	Lignite A	46.7	4.9	71.2	21.9	28,305	14.5	3.6

To convert kJ/kg to BTU/lb, divide by 2.326. Source: Reference [11]

The second one is produced by the World Energy Council (WEC) and is used by the BP Statistical Review of World Energy. According to BGR there are 1004 billion tons of coal reserves left, equivalent to 130 years of global coal output in 2011. Coal reserves reported by WEC are much lower - 861 billion tonnes, equivalent to 112 years of coal output.

Table 3: World coal production and export - 2011

Country	Coal Production (MMT)	Country	Coal Exports (MMT)
China	3,471.1	Indonesia	309.5
United States	1,004.1	Australia	284.5
India	585.9	Russia	123.7
Australia	414.3	United States	97.3
Indonesia	376.2	Colombia	75.5
Russian Fed.	333.8	South Africa	71.7
South Africa	253.1	Kazakhstan	34.0
Germany	188.6	Canada	33.7
Poland	139.2	Vietnam	24.4
Kazakhstan	116.7	Mongolia	22.1
Colombia	83.8	China	13.5
Other	711.6	Other	52.1
Total	**7,678.4**	**Total**	**1142.0**

Table 4: World coal import and consumption – 2011

Country	Coal Imports (MMT)	Country	Coal Consumption (MMT)
China	190.5	China	3,648.1
Japan	175.4	United States	925.3
Korea	129.2	India	655.3
India	105.7	Russia	234.7
Chinese Taipei	66.3	Germany	229.6
Germany	41.3	South Africa	182.7
United Kingdom	32.6	Japan	175.4
Russia	24.5	Poland	146.0
Netherlands	24.5	Korea	130.3
Turkey	23.8	Australia	119.7
Italy	23.5	Turkey	101.9
Other	265.1	Other	1,046.9
Total	**1,102.4**	**Total**	**7,595.9**

Coal reserves are available in almost every country worldwide, with recoverable reserves in over 70 countries. The largest reserves are found in North America, Russia, Europe, China and Australia respectively which account for more than 80% of global reserves. Australia is currently ranked fifth (5th) globally in terms of known coal reserves. The largest coal producing countries are China, the USA, India, Australia and the Russian Federation. Much of the global coal production is used within the country of origin, with approximately 16% of hard coal production traded on the international coal market. The vast majority of this coal is used for power generation, largely by pulverized coal combustion [12]. Australia is currently ranked fourth (4th) globally in terms of coal production. Coal is a major fuel for energy and steam production in coal-fired power plants across the globe. "Coal currently supplies around 30% of primary energy and 41% of global electricity generation. Coal use is forecast to rise over 50% to 2030, with developing countries responsible for 97% of this increase, primarily to meet improved electrification rates." [13].

4. COAL MINING CHALLENGES IN BANGLADESH

Bangladesh is very lucky that it has got substantial natural gas resource and significant but almost untapped high quality coal resource. There is also plenty of scope to generate solar power, wind power, energy from bio fuels. Many countries of the world like Japan, Korea do not have any basic fuel resource yet they are among the top developed nations. They import almost their entire requirement of the fuel for energy generation from highly competitive energy market. Several countries do not have enough basic fuel to meet their huge demand like China, India, and USA. These countries import energy from energy rich countries to fuel their economy.

Bangladesh energy market is not very large. Our reserve/ resource is definitely enough to meet our market demand for a long term. But due to lack of appropriate vision, good management and lack of political commitment we failed to economically explore and exploit the resources to utilize these for economic development. Our valuable coal resource remains mostly unexplored, our potential off source petroleum resource remains unprotected, and our discovered resource is also poorly managed and is not professionally developed. A 50 + year old gas industry is not yet self reliant, we do not have professional reservoir management, we do not have exploration, depletion policy and utilization strategy. of gas resource,. We have no practicing mining professional in mine sector, no mining policy or strategy. Trained human resources could not be retained due to inappropriate work environment. Massive brain drain has made our energy sector management virtually ineffective.

Unfortunately our small country Bangladesh of 150 million people has no appropriate strategy. There is a energy policy which is not properly administered. Electricity generation in Bangladesh is overwhelmingly gas based. More than 85percent of evening peak demand is catered by natural gas (This is followed at a distant by liquid fuel, and coal with generation shares of 6.76percent and 5.41percent respectively. Hydropower accounts for insignificant 2.45 percent of generation. The fuel mix if recalculated using the derated generation capacity, share of gas based generation reduces marginally to 83.45 percent; share of liquid fuel and hydro based generation increases to 7.55 percent and 4.60 percent respectively. Government could not adopt appropriate strategy to explore and exploit coal, the only other major energy resource. In the present crisis situation It is felt prudent to discuss about coal situation in Bangladesh. From the information presented in a recent CPD discussion in Dhaka, it is seen that, Bangladesh does not have any choice but to start coal mining without delay adopting technically appropriate and economically feasible and environmentally friendly mining method.

5. COAL RESERVES OF BANGLADESH

The total coal reserves in 5 coal fields of Bangladesh are estimated to be 2.9 billion metric tons as shown in **Table 5**. This is energy equivalent to 67 tcf of gas. Recovery rate of coal from reserves varies with the choice of technology and method of mining. If modern mining technology can be adopted ensuring strong regulatory supervision and monitoring, about 85% coal from Barapukuria, Phulbari and Dighipara can be recovered. Khalaspeer can be ideal candidate for Coal Seam methane while we can wait for some years for technological development for mining giant Jamalganj coal mine.

Table 5: Coal reserves in Bangladesh

No.	Place/ Field (Discovery)	Depth (m)	Area (Sq. Km.)	Proven Reserve (MT)
1.	Barapukuria, Dinajpur (1985)	119-506	6.68	390
2.	Khalashpeer, Rangpur (1995)	257-483	12.00	143 (GSB), 685 (Hosaf)
3.	Phulbari, Dinajpur (1997)	150-240	30.00	572
4.	Jamalganj, Jaipurhat (1965)	900-1000	16.00	1050

Source: Petrobangla

The energy content of our mineable coal from three shallow depth mines of the five discovered mines is equivalent to 30Tcf of gas. This can be enough for our energy security for 30 years if properly mined... Leaving the black gold underground when the nation is suffering from serious crisis is not at a smart policy. The suffering masses of unbearable energy crisis must demand immediate government decision on coal mining in safe, economic and environmentally friendly manner. Community of the mine affected people must get properly compensated, relocated to modern mine city, should get a portion of the royalty of the coal mined from the locations which once used to be their own property.

Experts should advise how coal recovery can be maximized pursuing appropriate safe mining method minimizing and managing impacts Experts should propose appropriate relocation and rehabilitation policy for mine affected people. All over coal industry, environmentalists green groups always oppose mining .But government mostly ignore their theories and doctrines and allow mining companies continue mining adopting appropriate mining method. Bangladesh cannot be an exception to it.

The discovered fields differ in respect of depth ranging between 119-506 meters and 150-240 meters in Barapukuria and Phulbari respectively. The depth of the coal field discovered in Jamalganj is 900-1000 meters. The area covered by coal fields are rather limited and is about 70-80 square kilometre area.

6. COAL COMBUSTION PRODUCTS: CCPs

The combustion of pulverized coal in the furnace of a power station boiler results in the production of a number of solid products traditionally regarded as wastes but more accurately classified as coal combustion products (CCPs). Globally various terms to describe CCPs have arisen over time. Coal ash, pulverized fuel ash, CUB's, CCB's, CCR's, and CWR with an ever-extending list of new terms.

Table 6: Different types of Coal Combustion Products

Term	Definition
Coal Combustion Products	Coal combustion products (CCPs) include fly ash, bottom ash, boiler slag, fluidized-bed combustion (FBC) ash, or Due gas desulfurization (FGD) material produced primarily from the combustion of coal or the cleaning of the stack gases. The term coal ash is used interchangeable for the different ash types.
Fly ash	The finer ash produced in a coal-fired power station, which are collected using electro-static precipitators. Sometimes spelt as 'Dy ash'. This is also known as Pulverized Fuel Ash (PFA) is some countries. About 85+% of the ash produced is Dy ash.
Bottom ash	The coarse ash that falls to the bottom of a furnace. The molten ash adheres to the boiler tubes, eventually falling to the base of the furnace. In many furnaces there is a water system that rapidly cools this ash, so-called 'wet bottomed' ash. Usually <15% of the ash produced is bottom ash (BA), in some countries also known as furnace bottom ash (FBA)
Cenospheres	Hollow ash particles that form in the furnace gas stream. Sometime these particles will contain smaller ash spheres. They float on water and are usually collected from lagoons, where ash/water disposal systems are being used. Only 1 to 2% of the ash produced are cenospheres and with the reduction in ash/water transportation, fewer are collected/available
Conditioned ash	Where Dy ash is mixed with a proportion of water (10 to 20% by dry mass typically) in order that it can be transported in normal tipping vehicles without problems with dust for sale or disposal or interim stockpile.
Flue Gas De-Sulfurisation	Where a source of Calcium is injected into the furnace gas stream to remove sulfur compounds. In wet systems a slurry with ground limestone is sprayed in gas stream. After decomposition of the limestone the sulfur reacts with lime and after oxidization forms calcium sulfate. This Due gas desulphurization gypsum (FGD) is used in the gypsum industry as replacement for natural avpsum.

Based on input and suggestion provided from WWCCPN Associations across the globe, draft' definitions are provided in the **Table 6**. Numerous standards produced across the globe provide guidance and definitions for their use for example European EN 197-1, EN 450-1, US ASTM 618, South African SANS 1491-2, Canadian CSA 3000, Australian AS3582.1 and Indian 3812 parts 1 & 2.

The nature and properties of fly ash are dependent on a variety of factors that include the coal's mineral composition, furnace/boiler temperature, type and ineness of the coal and the length of time the minerals are retained in the furnace/boiler. Some of the more important properties of fly ash which are addressed in the specifications are the carbon content, the chemical and mineralogical properties, with the former, as assessed by measuring loss on ignition (LOI), potentially experiencing wide variation. Some typical compositions of fly ash produced by the main coal types are given in **Table 7**.

Table 7: Normal range of chemical composition for fly ash produced from different coal types (%)

Compounds	Bituminous Coal	Sub-bituminous Coal	Lignite
SiO_2	20 - 60	40 - 60	15 - 45
Al_2O_3	5 - 35	20 - 30	10 - 25
Fe_2O_3	10 - 40	4 - 10	4 - 15
CaO	1 - 12	5 - 30	15 - 40
MgO	0 - 5	1 - 6	3 - 10
SO_3	0 - 4	0 - 2	0 - 10
Na_2O	0 - 4	0 - 2	0 - 6
K_2O	0 - 3	0 - 4	0 - 4
LOI	0 - 15	0 - 3	0 - 5

Background and History of Coal Combustion Products (CCPs)

In the early days of the power generation industry, coal combustion products (CCPs) were considered to be a waste material and nearly all of the coal combustion products were land filled. In the course of time, the cementitious and pozzolanic properties of fly ash were recognized and studied by several individuals and institutions. The products were tested to understand their physical properties, chemical properties and suitability as a construction material. During the last few decades these "waste" materials have seen a transformation to the status of “by-products” and more recently “products” that are sought for construction and other applications. The initial CCPs were called cinders and were formed from burning lump coal on grates in stoker furnaces. These cinders were sometimes used as road gravel and sometimes as a lightweight aggregate in manufacturing masonry “cinder” blocks.

In the 1920's, more effective methods of firing power plant boilers were invented. These new processes involved burning pulverized coal instead of lump coal. While the process was a more efficient method of firing, the process generated an increased stream of fine combustion products and lower quantities of cinders. This fine combustion product is called fly ash, and the cinders that are relatively finer are called bottom ash. As environmental awareness and land filling costs have grown, CCP generators and government regulators have encouraged the beneficial use of industrial by-products, including coal ash. According to the American Coal Ash Association (ACAA), combustion of coal in the United States alone generated approximately 128.7 million tons of coal combustion products in 2002, including approximately 76.5 million tons of fly ash, 19.8 million tons of bottom ash, 29.2 million tons of flue gas desulfurization (FGD) materials, and 1.9 million tons of boiler slag (1). Of the fly ash produced, approximately 12.6 million tons were used in cement, concrete, and grout applications; and another 14.1 million tons were used in various other applications.

In some parts of the world, CCP utilization rates are much higher than that of the United States. For example, in the Netherlands CCP utilization is about 104% (Netherlands imports ash, as their supply is less than demand). CCP utilization in Denmark is approximately 90% and in Belgium over 73%. CCP utilization in other parts of Europe varies widely from around 10% to 60%. The United States is the world's second largest producer of fly ash (second only to China). However, CCP utilization in the United States is relatively low. This presents opportunities to make use of this valuable mineral resource. By 2002, approximately 45.5 million tons (35.4%) of coal combustion products were used in the United States. This percentage is expected to increase, as a result of the new uses for CCPs, increased awareness of proven technologies, and global focus on sustainable development.

The disposal cost of coal combustion by-products has escalated significantly during the last couple of decades due to significant changes in landfill design regulations. Utilization of CCPs helps preserve existing licensed landfill capacity and thus reduces the demand for additional landfill sites. Due to continued research and marketing efforts, We Energies was able to utilize 98% of coal combustion products in 2003 compared to only 5% in 1980. The use of CCPs in construction reduces the need for quarried raw materials, manufactured aggregates and Portland cement. Replacement of these virgin and manufactured materials with CCPs helps to reduce emissions associated with their manufacturing and processing. When fly ash and bottom ash are used beneficially as engineered backfill material, this material is replacing sand or gravel that would have been quarried and transported from various locations. The use of CCPs helps preserve sand and gravel pits and quarries as well as provides construction cost savings associated with their operation. It is also important to keep in mind that every time Portland cement is replaced or displaced with fly ash, CO_2 and other emissions to the atmosphere from cement production are reduced by decreasing the need for limestone calcinations as well as the fossil fuel that is consumed for production.

CCPs Generation

In the coal combustion process, CCPs are also generated in direct proportion to the variety and quantity of coal consumed. The pulverized coal is burned in the furnace to generate heat, and the hot gases then pass around the bank of tubes in the boiler and are eventually cleaned and discharged through the plant chimney. In large power plants that consume large quantities of coal, substantial quantities of coal ash are produced. This ash that is collected in electrostatic precipitators or baghouses is called fly ash. In electrostatic precipitators the flue gas is passed between electrically charged plates where the fly ash particles are then attracted to the plates. Baghouses can also be used to collect ash with bags that filter the fly ash out of the flue gas stream. The fly ash particles are then periodically knocked off the plates or bags and fall into the hoppers located at the bottom of the electrostatic precipitators or baghouses. The fly ash is then pneumatically transported to storage silos. The storage silos are equipped with dry unloaders for loading dry bulk semi tankers or rail cars and wet unloaders for conditioned ash or disposal applications.

The ash collected from pulverized-coal-fired furnaces is fly ash and bottom ash. For such furnaces, fly ash constitutes a major component (80 to 90%) and the bottom ash component is in the range of 10 to 20%. Boiler slag is formed when a wet-bottom furnace is used. The ash is kept in a molten state and tapped off as a liquid. The ash hopper furnace contains quenching water. When the molten slag contacts quenching water, it fractures, crystallizes, and forms pellets, resulting in the coarse, black, angular, and glassy boiler slag. The boiler slag constitutes the major component of cyclone boiler by-products (70 to 85%). The remaining combustion products exit along with the flue gases. Currently, We Energies power plants do not produce boiler slag. Flue gas desulfurization (FGD) material is the solid material resulting from the removal of sulfur dioxide gas from the utility boiler stack gases in the FGD process. The material is produced in the flue gas scrubbers by reacting slurried limestone or lime with the gaseous sulfur dioxide to produce calcium sulfite. Calcium sulfite can be further oxidized to synthetic gypsum (calcium sulfate) which has the same chemical composition as natural gypsum. The dewatering system removes water from the calcium sulfate or synthetic gypsum slurry leaving the FGD absorber modules using centrifuges or belt filter presses. A belt conveyor system transports the dewatered materials from the dewatering building to an adjacent storage shed.

7. SUMMARY AND CONCLUSION

Starting from its discovery in 1673, coal has been the primary source of energy until 1960s. The use of oil for transportation overtook coal as the largest source of primary energy after 1960s. However, coal still plays a vital role in the words primary energy mix, providing 24.4% of global primary energy needs in 2003 and 40.1% of the world’s electricity. Although in the early days CCPS were considered to be a waste material, during the last few decades, these waste materials are being used as partial replacement of cement or sand to enhance workability of fresh concrete, to reduce heat of hydration and to improve concrete durability and resistance of salt attack. The nature and proportion of fly ash are dependent on a variety of factors that include the coal’s mineral composition, furnace/ boiler temperature, type and in excess of the coal and the length of time the minerals are retained in the furnace/ boiler. However based on the detailed discussion on the coal and its combustion production generated globally, the following points can be noted:

a) Over 850 Giga tones proven coal reserves exist which is enough to last more than 130 yrs at current rate of production.

b) Coal currently supplies around 30% of primary energy and 41% of global electricity generation.

c) Coal use is forecast to rise over 50% to 2030 with developing countries responsible for 97% of this increase, primarily to meet improved electrification rates.

d) In the modern coal fired power station, 80-85% of the coal ash is generated through furnace gas as Fly ash (FA) and the remaining (15%-20%) produced in the boilers as bottom ash.

e) CCPs once considered as waste materials, now a days have been transformed to the status of “ by products” and more recently” product, that are sought for construction and other applications.

f) The use of CCPs in construction reduces the need for quarried raw materials, manufactured aggregates and Portland cement. In concrete fly ash can be used as partial replacement of cement or sand to improve workability, impermeability and resistance to chemical attack and also to reduce heat of hydration.

g) Coal reserves in 5 (five) coal field of Bangladesh are estimated to be 2.9 billion metric tons which is energy equivalent to 67 tcf of gas. The energy content of mineable coal is equivalent to 30 tcf which can ensure the energy security for 30 years.

h) The yearly coal production rate of Barapukuria coal mine is 1 million ton of which the generation of fly ash is 65 thousand ton.

i) According to ACAA, the amount of CCPs generated at USA in 2002 is 129 million tons which 77 million tons are fly ash and 20 million tons bottom ash. Out of the produced fly ash, approximately 126 tons (17%) were used in cement, concrete and application and another 14.1 million tons were used in various other application where as CCP utilization in Denmark is average 90% and Belgium over 73% and in other parts of Europe varies widely from average 10% to 60%. This percentage is expected to increase as a result of the new uses of CCPs, increased awareness of proven technologies and global focus on sustainable development.

j) Proper investigation must be carried out to asses the adequacy / suitability of the indigenously generated CCPs from Barapukuria Coal fired power plant for the production of cement, concrete etc which will reduce the import of costly cement clinker and also ensure the proper management of the CCPs that will other will be dumped over fertile lands. The concerned research organization and technical universities can take initiatives for such research works through the necessary research grant from UGC / Ministry of Education.

k) Appropriate vision, good management, adequate political commitment is necessary to economically explore and exploit the resources including coal to utilize these for national development.

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