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ANALYSIS AND COMPARISON OF DIFFERENT COAL FIELDS AND IMPORTED COAL IN BANGLADESH

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Abstract: The invention of coal in Barapukuria and Khalaspir, Bangladesh, has opened the main source of fuel in our country. The proper utilization of these resources requires a better understanding of the rank, formation, structure, composition and calorific value and method of analysis of the material. For this purpose, some new coal samples were collected from Barapukuria and Khalaspir coal fields at different depth and also collected some imported coal samples from Birampur Hard Coke Limited, Dinajpur, Amin Brick Field, Phulbari, and Geological Survey of Bangladesh. Coal has been traditionally determined by important parameters such as, bulk density, free swelling index, calorific value, sulfur, moisture, fixed carbon, volatile matter, ash content has been determined by physical, proximate and other analysis. The moisture content of Bangladeshi and imported coal are near about the same. The ash, sulfur content of Bangladeshi coal is lower than those of imported coal. On the other hand, calorific value, volatile matter, fixed carbon content of Bangladeshi coal are higher than those of imported coal.

Keywords: Barapukuria**,** Coal, Calorific value, Sulfur, Ash.

Introduction

Coal is used as a primary fuel in the world to meet the demand of energy. The estimated worldwide production of coal is more than 550 million ton [1]. Although coal is a very complex and heterogeneous material, it is the most plentiful resource and will continue to be principle fuel used for the electricity generation, hard coke and brick fields etc in our country [2]. The geological history of Bangladesh is very complex. In our country, there are a lot of mineral assets under the green cropped land [3]. From 1857 to 1957 many Geologists expressed with hope that coal mine would be found under the green cropped land in Bangladesh [4]. Their expectations were vindicated in 1959 when in course of searching for oil drilled a hole in Bogra where Gondwana coal was encountered at a depth of 2381 m from the surface. After that, the Geological Survey of Bangladesh (GSB) discovered five coal

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fields in Bangladesh. The estimated coal reserve is more or less 3300 million metric ton where in situ reserve is 2247 million metric ton in our country [5]. Among these coal fields, coal has been mining only from Barapukuria coal field which is not so enough in quantity to meet the demand of coal as a fuel in our country since there is no petroleum resource in our country. The socio-economic condition of our country as well as the environmental degradation due to deforestation can be improved by proper and effective utilization of this coal. The energy crisis in our country also can be decreased by making proper use of this coal. So proper chemical and geochemical investigations on Bangladeshi and imported coal are so necessary for the improvement of our country.

Materials and Methods

Materials

Sample Collection: The fifteen samples were collected from Bangladesh. Ten samples are Bangladeshi coal and five samples are imported coal that use Bangladeshi coke industry and brick field. Five coal samples were collected from Barapukuria coal mine. Among the four coal samples were collected with my own attempt from under the ground of coal mine which is different in depth. One dust sample collected from the open field where the dust coal is stored, five coal samples of Khalaspir coal mine were collected from Geological Survey of Bangladesh (GSB) [6]. Again, imported samples were collected from three different places one from Birampur Hard Coke Ltd, Dinajpur, Amin Bricks Field, Phulbari and other from GSB. The collected samples were thoroughly mixed, air dried over night and crushed for the various analysis preserved followed by ASTM D 2013-00 [7].

Methods

Bulk Density: It is usually determined by a minor variation of what is called Eureka method of Archimedes, which is best on buoyancy in water [8]. Generally, in such procedures the rock is weighed when dry and then again when sub-merged in water. Most rocks including coal absorbs water into pores and crevices and on being sub-merged, show a constant change in weight. So a correction made to take the absorbed water into account. The bulk densities were calculated by using following USGS formula:

$$\text{Bulk Density, BD} = \frac{W}{W_1 - (W_2 - W_3)}$$

Where,
W = Dry Weight of sample (after setting over night)
W_1 = Wet weight of sample

W_2 = Weight of sample under water with wire
W_3 = Weight of wire as when in use

Free Swelling Index: It is a measure when it is heated (without restriction) under the prescribed conditions as per ASTM D 720-67. The collected samples were passed through 250 µm mesh sieve then One gram of the sample weighed into a silica crucible. The silica crucible with cover placed on a tripod stand. Then it was heated for seven minutes on Bunsen burner flame. Then the coke button obtained was compared with standard profiles and for each sample the appropriate free swelling numbers were determined.

Gross Calorific Value: The sample was burned in a bomb calorimeter (C 400, Germany) in pure oxygen 30kp/cm^2 under the prescribed conditions as per ASTM D 5865-04. The heat involve by burning raised the temperature of the calorimeter system around 10-15 minutes. After the ignition, the heat is changed between bomb and the surrounding inner vessel was completed. The temperature was measured and used to calculate the heat of combustion. The thermal capacity of the adiabatic system had been evaluated by the combustion of the reference substance i.e. benzoic acid under the same experimental conditions. The value the heat of combustion of benzoic acid at 250^{0}C is known (i.e. 6312 Cal/gm). Heat evolved by combustion of the ignition wire and the production of sulfuric acid was taken into account in the calculation.

The interior of the bomb was washed with distilled water until the washing were free of acid and the washing was filtrated with standard sodium carbonate solution (1 cc Standard Na_2CO_3=10 BTU/Ib).

Gross Calorific Value, CV= $\frac{C.\Delta t - (\theta_n + \theta_s + \theta_z)}{mp}$ Cal/gm

Where,

C= Thermal capacity of calorimeter

Δt = Difference of temperature

θ_z =Heat of combustion of wire

θn =Heat evolved by formation of HNO_3 acid

θs =Heat evolved by formation of H_2SO_4 acid

Sulfur: The percentage of sulfur was determined by Bomb Washing Method used in ASTM D 3177-84. In this method sulfur is precipitated as $BaSO_4$ from oxygen bomb calorimeter washing and the precipitate is filtered, washed ignited and weighed.

$$\% \text{ Sulfur, S} = \frac{(W_2 - B)\times 13.738}{W_1}$$

Where,

W_1= Weight of sample taken

W_2= Weight of $BaSO_4$ precipitated

B= Weight of $BaSO_4$ correction/ Blank correction

Proximate Analysis: It was carried out with ASTM D 5142-02. It involved the determination of moisture, volatile matter, ash and fixed carbon contents of coal.

Moisture Content: The collected samples were passed through 250 µm mesh sieve. One gm sample was heated in crucible without covers in the drying oven at 107^0C for one hour. The percent loss in weight accounted for the moisture content and it was calculated with the formula:

$$\% \text{ Moisture, M} = \frac{W_2}{W_1}\times 100$$

Where,
W_1=Weight of sample taken
W_2= Loss of weight

Volatile Matter: The collected samples were passed through 250 µm mesh sieve. The silica crucible was pre-heated in muffle furnace for seven minutes at 900^0C and cooled. One gm sample placed in a crucible and raised the temperature of the finance at a rate of 50^0C/min to 950 ± 20^0C and hold for seven minutes. The weight of the heated sample was then determined. The percent loss in weight gave the volatile matter content of the coal and it was calculated with the formula:

$$\% \text{ Volatile Matter, VM} = (\frac{W_2}{W_1}\times 100) - M$$

Where,
W_1= Weight of the sample taken
W_2= Loss of weight
M=Moisture

Ash Content: The collected samples were passed through 250 µm mesh sieve. The silica crucible was pre-heated in muffle furnace for one hour at 800^0C and cooled. One gm sample was placed in a crucible and raised the temperature of the finance at a rate of 50^0C/min to 800 ± 20^0C and hold for two hours. The crucible was then cooled in the desiccators and weighed. The incombustible residue of the coal was then weighed. The percent ash content from the weight of the incombustible residue was determination with the formula:

$$\% \text{ Ash, A} = \frac{W_2}{W_1} \times 100$$

Where,

W_1= Weight of the sample taken

W_2= Weight of ash residue after the ash test

Fixed Carbon: Fixed carbon of the coal was determined by the calculation with the relation:

%Fixed Carbon, FC =100-(%Moisture+%Ash+%Volatile Matter)

Results and Discussion

Results:

The results of the analysis are presented in Table 1 and 2.

Table 1: Results of Bulk Density, Free Swelling Index, Calorific Value and Sulphur of Bangladeshi and Imported Coal

Sample Collection Country and Location	Sample Number	Sample Collection Depth (meter)	Parameters			
			Bulk Density	Free Swelling Index	Calorific Value (Btu/Ib)	Sulfur (%)
Bangladesh, Barapukuria Coal Mine	BP-1	300	2.08	3.5	14200	0.59
	BP-2	330	1.94	2	12510	0.99
	BP-3	370	1.98	2.5	13110	0.73
	BP-4	460	2.20	2.9	14170	0.69
	BP-5 (Dust)	460	-	3.6	10750	0.57
Bangladesh, Khalaspir Coal Mine	KP-1	290.78	1.48	4.5	12800	0.99
	KP-2	296.88	1.28	3.5	13200	0.95
	KP-3	302.97	1.29	4.5	12931	1.40
	KP-4	306.02	1.62	7.0	14085	1.80
	KP-5	312.12	1.40	6.5	14714	0.95
India, South Jahria	IJ-1	-	1.18	3.5	10740	1.21
India, Tirap,	IT-2	-	1.80	5.0	10980	1.34
India, Bapon	IB-3	-	1.46	3.8	8950	2.10
India, Tamabil	IM-4	-	1.24	2.5	9110	3.50
Australia	IA-5	-	1.16	3.5	10750	1.50

The coal rank decreases with decreasing of bulk density mainly due to increase the moisture fraction. Higher rank coal may have density over1.5 gm/cc and lower rank coal may have density lower than 1.3 gm/cc. In case of Bangladeshi coal, the determined bulk density for

BP-1, BP-2, BP-3, BP-4 were 2.08, 1.94, 1.98, 2.20gm/cc and for KP-1, KP-2, KP-3, KP-4, KP-5 were 1.48, 1.28, 1.29, 1.62, 1.40 gm/cc respectively. In case of imported coal the determined bulk density for IJ-1, IT-2, IB-3, IM-4 and IA-5 were 1.18, 1.80, 1.46, 1.24 and 1.46 gm/cc respectively. It is observed from the analytical data that Bangladeshi coal exceeds the higher rank limit of coal and imported coal have the bulk density of lower rank coal. So Bangladeshi coals are higher rank coal and imported coals are lower rank coal.

The test for FSI is an empirical one and FSI values can be used to indicate the coking character of coal when burned as a fuel. The higher FSI the higher coking character of coal. Medium volatile coal is generally expected to have good coking properties. The free swelling index of Barapukuria coal mine varied from 2.0 to 3.6 giving an average 2.8. The FSI in the dust sample of Barapukuria coal mine was 3.6. The free swelling index of Khalaspir coal mine varied from 3.5 to 7.0 giving an average 5.25. On the other hand, the free swelling index of imported coal varied from 5.0 to 2.5 giving an average 3.66. From the data it is concluded that Bangladeshi and imported coal have both coking and non coking properties.

The ranking of coal depends on calorific value. The calorific value is the most important value determined for coal that is to be used for heating purpose. The calorific value for bituminous coal ranges from 12000 to more than 15000 Btu/Ib and for sub-bituminous coal ranges from 8300 to 11500 [9]. In case of Barapukuria coal mine, the CV varied from 14170 to 12510 Btu/Ib. In case of Khalaspir coal mine, the CV varied from 14714 to 12800 Btu/Ib. On the other hand, In case of imported coal, the gross CV varied from 8950 to 10980 Btu/Ib. It was found that, the gross CV of Bangladeshi coal was higher than that of imported coal. It was also shown from the CV that Bangladeshi coals are bituminous and imported coal are sub-bituminous.

The sulfur content of coal may vary from 0.7-4.0 weight %. It is the most important factor of coal combustion because it form oxides with oxygen when burnt and the resulting sulfur oxides are considered to be the most toxic of air pollutants. Oxides of sulfur cause formation of smog, it also contributes to acid rain. These oxides are one of the foulest enemies of the environment and highly hazardous to human health. It also affects the use of coal. It lowers the quality of coke and thus affects the production of iron products [10]. The determined sulfur for BP-1, BP-2, BP-3, BP-4, BP-5 were 0.59%, 0.99%, 0.73%, 0.69%, 0.47% and for KP-1, KP-2, KP-3, KP-4, KP-5 were 0.99%, 0.95%, 1.40%, 1.80%, 0.95% respectively. In case of imported coal the determined sulfur for IJ-1, IT-2, IB-3, IM-4 and IA-5 were 1.21%, 1.34%, 2.10%, 3.50% and 1.50% respectively. It was shown that sulfur content of

Bangladeshi coal was lower than that of imported coal and it was less harmful to environment.

Table 2: Proximate Analysis of Bangladeshi and Imported coal

Sample Number	Proximate analysis			
	Moisture (%)	Volatile Matter (%)	Ash (%)	Fixed Carbon (%)
BP-1	3.60	36.00	5.51	54.89
BP-2	2.71	27.33	12.30	57.66
BP-3	3.20	32.00	6.00	58.80
BP-4	3.41	32.13	14.32	50.14
BP-5 (Dust)	5.23	23.32	22.76	48.69
KP-1	3.00	28.50	15.60	52.9
KP-2	2.85	26.93	10.20	60.02
KP-3	2.70	25.60	8.95	62.75
KP-4	2.50	26.92	8.05	62.53
KP-5	3.45	25.51	6.11	64.93
IJ-1	3.10	15.30	22.40	59.20
IT-2	1.75	34.26	11.21	52.77
IB-3	2.29	36.83	19.32	41.55
IM-4	2.20	23.84	29.81	44.15
IA-5	2.90	19.95	28.92	48.23

The moisture content of coal can range from 2 to 15 % in bituminous coal to nearly 45% in lignite. The higher the moisture content, the lower the energy values of coal and so the bulk density. Higher moisture content is undesirable in general [11]. The estimated moisture content for BP-1, BP-2, BP-3, BP-4, BP-5 were 3.60%, 2.71%, 3.20%, 3.41%, 5.23% and for KP-1, KP-2, KP-3, KP-4, KP-5 were 3.00%, 2.85%, 2.70%, 2.50%, 3.45% respectively. For imported coal the estimated moisture content of IJ-1, IT-2, IB-3, IM-4 and IA-5 were 3.10%, 1.75%, 2.29%, 2.20%and 2.90% respectively. It was found that, the moisture content of Bangladeshi coal was slightly lower than that of imported coal**.** From the data, we can conclude that moisture content of Bangladeshi and imported coal is low and they have high energy value.

The volatile matter of coal sample generally varies from 8.8 to 45.5 % by weight [12]. This volatility includes lighter aromatic hydrocarbon, phenols and other chemicals. Lignite and bituminous coals have high volatile matter content where as anthracite has very low volatile matter content. Among the four coal samples of Barapukuria coal mine, the highest volatile matter was 36.00% and the lowest was 27.33% giving an average 31.86%. In the dust sample of Barapukuria coal mine the volatile matter was 23.32%. Among the five coal samples of Khalaspir coal mine, the highest volatile matter was 28.50% and lowest was 25.51% giving an average 26.69%. On the other hand, among the five imported coal samples, the highest volatile matter was 36.83% and the lowest was 15.30% giving an average 25.03%. The volatile matter content of Bangladeshi coal was higher than that of imported coal. According to classification of coal based on volatile matter and coking coal, the volatile matter indicates that the Bangladeshi and imported coal are high volatile to medium volatile.

Coal ash is the residue remaining after the combustion of coal under specified conditions. It is different in chemical composition and is usually less than mineral matter originally present in coal. Ash as high as 50% has been observed, 5-15% is more typical [11]. Among the four coal samples of Barapukuria coal mine, the highest ash content was 14.32% and the lowest was 5.51% giving an average 9.53%. In the dust sample of Barapukuria coal mine, the ash content was 22.76%. Among the five coal samples of Khalaspir coal mine, the highest ash content was 15.60% and the lowest was 6.11% giving an average 9.7%. On the other hand, among the five imported coal samples, the highest ash content was 29.81% and the lowest was 11.212% giving an average 22.33%.

As fixed carbon increases the coal rank increases. The fixed carbon of bituminous coal varied from 50 to 70 % and sub bituminous coal varied from 30 to 57 % [13]. Among the four coal samples of Barapukuria coal mine, the highest fixed carbon content was 58.80% and the lowest was 54.89% giving an average 55.37%. In the dust sample of Barapukuria coal mine, the fixed carbon content was 48.69%. Among the five coal samples of Khalaspir coal mine, the highest fixed carbon was 64.93% and the lowest was 52.9% giving an average 60.62%. On the other hand, among the five imported coal samples, the highest fixed carbon content was 59.20% and the lowest was 41.55% giving an average 49.18%. It was found that, the fixed carbon content of Bangladeshi coal was higher than that of imported coal.

Conclusion

From the analytical results and subsequent rank classification it is found that, Barapukuria and Khalaspir coal are bituminous type except the coal samples (BP-5). On the other hand, the imported coal i.e. Indian and Australian coals are sub bituminous type except the coal samples (IT-2).

The ash content found low in the coal of both the Barapukuria and Khalaspir deposits except the coal samples (BP-4 and KP-1) and the ash content in imported coals is high. The sulfur content is found less than 1% in both the Barapukuria and Khalaspir coal except sample no (KP-3, KP-4) and in imported coal sulfur content is found greater than 1%.

Coking coal is totally imported in our country. If the coal research can be developed and the coking coal can be separated from coal of Barapukuria coal mine then it would be used as a coking coal in our country. And also if the dust sample of Barapukuria coal mine can be recovered then it would be used as coking coal to meet the demand of hard coke in our country.

Finally it is concluded that, Bangladeshi coal is better for power generation, brick fields, hard coke, steel production etc due to high calorific value than imported coal and has no adverse effect on environment due to low sulfur content.

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