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Characterization of Coal Spoil Recovered from Coal Mine Drainage Water

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Abstract

Barapukuria Coal Mine situated in the district Dinajpur. Bangladesh is playing an important role in the economy of this country by the mining of top quality coal. With coal mining, mine waste is also generated called coal spoil. Coal spoil can impose environmental threat if not treated carefully. In contrast, it can also be converted to value added product. In the present work, coal spoils collected from Barapukuria coal mine drainage water were investigated to determine the quality of the samples by physico-chemical analysis (proximate and ultimate analysis) as well as by heating value determination. 50% of carbon was detected in the samples after elemental analysis, with sulfur content less than 0.4%. Calorific value around 9300 btu/lb was obtained for the coal spoil. Moreover, moisture content, ash, volatile matter content and fixed carbon also provided fruitful information regarding the quality and economic prospect of the samples in comparison to the quality of Barapukuria coal.

Keywords

Coal Spoil, Calorific Value, XRF, XRD, Particle Size Analysis, Thermal Analysis

1. Introduction

Coal spoil (CS) is a coal mining waste generated during mining and beneficiation of coal in coal mine. It is composed of various types of minerals, rocks and carbonaceous materials depending on the quality of mine and process of mining [1]. CS may include coarse discard which may result from cutting roadways, underground development work in the mine; and fine particles generated from washing process. This CS can cause serious environmental pollution. Actually coal mining has drastically adverse environmental impacts, including interference with ground water, land subsidence, impact of water use on flows of rivers and consequential impact on other land-uses, mining wastes disposal, geological hazards, visible and aesthetic offenders, sometimes damaging infrastructure, and potential ecological havoc, among of which mining wastes disposal has less progress considering disposal methods, utilization of mining wastes and its impact on environment [2] [3] [4] [5] [6]. As a result mining method can be made sustainable by minimizing waste production. This can be achieved by reusing the waste in different sectors. Therefore waste reduction and reuse have recently become the most preferable methods in waste management. Reusing of coal spoil totally depends on the types of spoil.

Spoil containing high carbonaceous material can be used as fuel in power plant. But before waste utilization, it is necessary to categorize the spoil.

In Bangladesh, coal reserves have been discovered in Jamalganj, Barapukuria, Khalashpir, Dhighipara and Phulbari. Among these reserves, only Barapukuria is having underground mining operations with a geological reserve of 390 million tons [7]. This underground mining operation needs to pump out 1500 m^3 of water per hour to avoid flooding inside the mine [8]. This water carries out 200 mg of coal spoil per liter. Precipitator is used to settle the spoil from drainage water. But tons of coal spoils per month still overflows with the drainage water that is discharged from the mine to the nearby areas. Due to lacking of improper mine waste water disposal and unknown data about the production and categories of coal mining wastes in Barapukuria, the environment is being ruined day by day. Drainage water containing CS is causing environmental pollution because most coal spoils are in tyrannically heavily loaded with heavy metals [9] with coal dust. Moreover, in dried conditions these fine particles can produce serious dusting problem. This spoil is used as fuel in domestic and small industries which may not be appropriate as per its quality. So, proper characterization of this spoil is required to upgrade this material for proper economic utilization, which eventually will reduce pollution. In this work, an attempt was made to characterize this coal spoil in order to find a solution of pollution problem and appropriate economic utilizations.

2. Materials and Methods

Initially, samples were collected from three different spots adjacent to Barapukuria coal mine co. Ltd. Samples were collected from the deposits of coal spoil which were made by local people collecting them from the channels that carry coal mine drainage water. Some coal samples were also collected for comparing between coal and coal spoil. These samples were then taken to laboratory and their moisture content, volatile matter, ash, fixed carbon were measured by respective ISO/ASTM methods. Calorific values of samples were determined by using Parr 6400 calorimeter. CHNS values of the samples were detected by elemental analyzer; Thermo Flash-2000 and particle size distribution was measured by laser based particle size analyzer, Microtrac 3500. Rigaku ZSX Primus XRF machine equipped with an end window 4 kW RH-anode X-ray tube was used for XRF analysis of the CS ash which was prepared by burning CS for two hours at 815˚C. The XRD pattern of CS were determined by Bruker D8 Advance diffractometer with Cu Kα = 1.5406 angstrom. TG/DTA studies were performed by using SII EXTAR 6000, TG/DTA 6300.

3. Results and Discussions

The Barapukuria coal mining waste mainly comprises fine carbonaceous materials with clay. This material is washed and carried away with the mine drainage water. Figure 1(a) shows the view of coal mine drainage water running though the channel. This water carries the CS. Local people collect this CS from the channels and dump them along the road side for drying as indicated in Figure 1(b). Samples from three different spots were collected and were indicated as sample CS-1, CS-2 and CS-3 as shown in Figure 2. These were found as lumpy mass of fine particles.

(a)

(b)

Figure 1. (a) Drainage water channel carrying coal spoil; (b) Coal spoil dumped along road side for drying (indicated by arrow).

CS-1 CS-2 CS-3

Figure 2. Collected coal spoil samples for laboratory analysis in the form of lumpy mass of fine particles.

3.1. Proximate and Ultimate Analysis of CS

Table 1 Shows the proximate analysis (wt%) and heating value results of collected CS samples from Barapukuria coal mine sites. Lowest moisture content (as received) was found for sample CS-1 nearly about 10% whereas, around 34.69% and 29.04% of moisture content (as received) was found for both CS-2 and CS-3 indicating that CS-1 was more dried than CS-2 and Cs-3. As earlier stated, samples are dumped at different places for air drying; CS-1 was collected in dried condition. However, CS-2 and CS-3 were collected in wet condition from sampling sites. In case of inner moisture content, all the samples had moisture content in between 2% to 3%. Maximum inner moisture content was found for CS-1 and it was 2.47% and minimum 2.34% for CS-3. These all are similar to the inner moisture content of Barapukuria Coal. Above 25% of volatile matter was found for CS-2, which was maximum, while CS-1 and CS-3 resulted around 24% and 24.5% of volatile matter respectively. The volatile matter of coal sample of Barapukuria was around 29.20% indicating that the lower volatile matter was found in CS in comparison to the Barapukuria coal. Maximum 35.5% ash was obtained from CS-1, whereas, nearly 30% ash was found for sample CS-2 and 31.5% for CS-3. On the other hand, Barapukuria coal had only 12.4% ash indicating that the experimental CS contains high metallic contaminant than Barapukuria coal. As a result heating value of experimental samples should be less than that of Barapukuria coal. Fixed carbon content of CS-1, CS-2 and CS-3 were shown 38.18%, 42.40% and 41.58%, respectively which were near to the fixed carbon value of Barapukuria coal. Calorific values obtained from coal spoil were found a little less value than that of the coal of Barapukuria coal mine. Calorific value of Barapukuria coal was around 10,891 Btu/lb-11,040 Btu/lb while CS-1, CS-2 and CS-3 provided calorific values 9813.82 Btu/lb, 9936.43 Btu/lb and 8145.35 Btu/lb; respectively indicating that experimental CS has a little less heating capacity than that of Barapukuria coal; however this CS

Table 1. Proximate analysis (wt%) and calorific value (BTU/lb) of coal spoil.

Analyzing Parameters	CS-1	CS-2	CS-3	Barapukuria coal
Moisture (as received)	9.17	34.69	29.04	-
Inner-moisture	2.47	2.39	2.34	2.37
Ash content	35.51	29.98	31.58	11.25
Volatile matter	23.84	25.23	24.5	31.08
Fixed carbon	38.18	42.4	41.58	55.34
Calorific value	9813.82	9936.43	8145.35	10,547

has good potential for using as an energy fuel. Ultimate analysis of coal spoil is shown in Table 1. Around 50% of carbon content was found from all of the coal spoil samples while Barapukuria coal had 68.72%. Marginally higher carbon content was found in Barapukuria coal in comparison to the spoil. That is why; higher calorific value was obtained for Barapukuria coal. Sulfur content is a vital issue in case of coal quality as it is strongly connected with environmental pollution. Barapukuria coal has 0.32% - 0.5% sulfur whereas maximum 0.43% sulfur was evident for CS-2, other two spoil samples CS-1 and CS-3 had similar result with that of coal (Table 2).

3.2. Particle Size Distribution of CS

As coal spoil was found as lumpy mass of fine particles, in dried condition it can produce serious dust problems. Particle size distribution of CS-1, CS-2 and CS-3 is shown in Figure 3. In each of the cases bimodal distribution was found for coal spoil samples with similar patterns. For CS-1, two major peaks were found around 20 μm and 250 μm. CS-2 showed peaks around 20 μm and 220 μm and CS-3 had peaks around 20 μm and 300 μm. All the coal spoil samples had similar bimodal with micron size particles ranging from 2 to 1000 μm. These micron size particles can cause dust problem. However, having high carbon content and high calorific values, this dust can be utilized in coal fired thermal power plant as an alternative of pulverized coal.

3.3. XRD Analysis of CS

X-ray diffraction (XRD) patterns of CS-1, CS-2 and CS-3 are shown in Figure 4, which represents the main mineralogical phases of CS; graphite, quartz and kaolinite. The presence of graphite represents carbon and kaolinite represents clay indicating that the Barapukuria CS comprises with coal and clay.

3.4. XRF Analysis of CS

Chemical composition of coal spoil ash was analyzed after burning it at 850˚C for two hours which is shown in Table 3. High concentrations of SiO_2, Al_2O_3 and Fe_2O_3 were found in each sample. 3% of TiO_2 were found in all the samples which are quite promising. Moreover, traces of heavy metals like Cu, Pb, Zn, Mn,

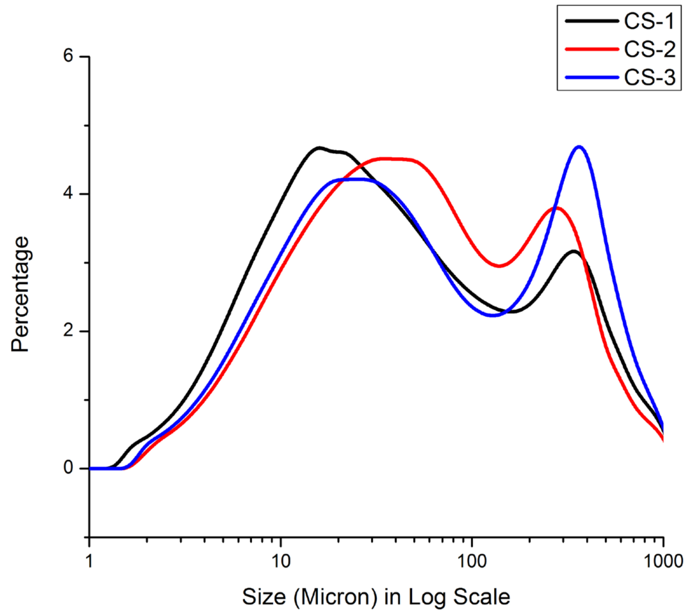


Figure 3. Particle Size Distribution of CS-1, CS-2 and CS-3

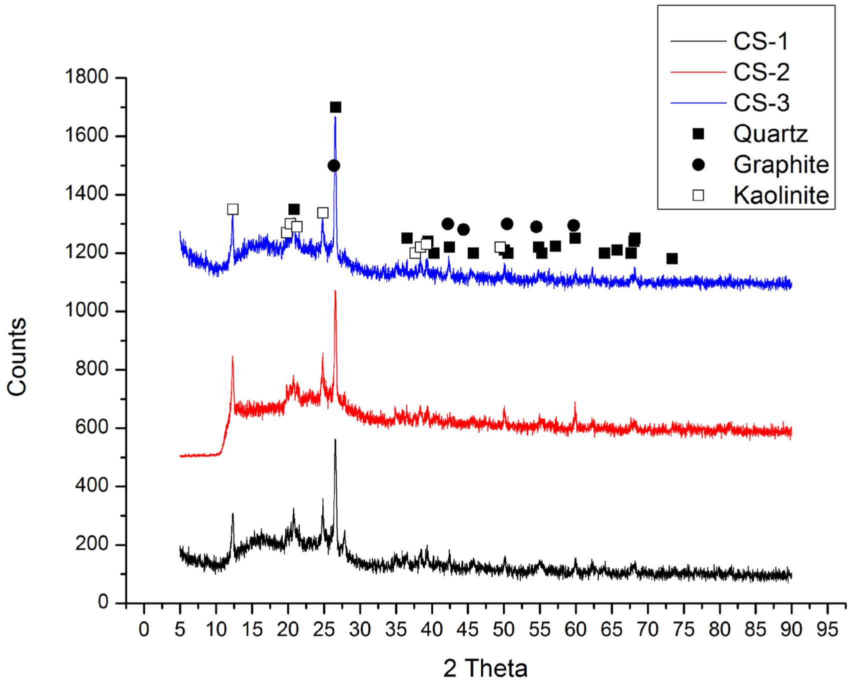


Figure 4. XRD patterns of CS-1, CS-2, and CS-3

Table 2. C, H, N, S analysis of coal spoil.

Sample	C %	H %	N %	S %
CS-1	49.67	3.06	2.8	0.36
CS-2	55.24	3.45	1.06	0.43
CS-3	53.62	3.33	0.97	0.34
Barapukuria coal	68.72	4.31	0.92	0.32

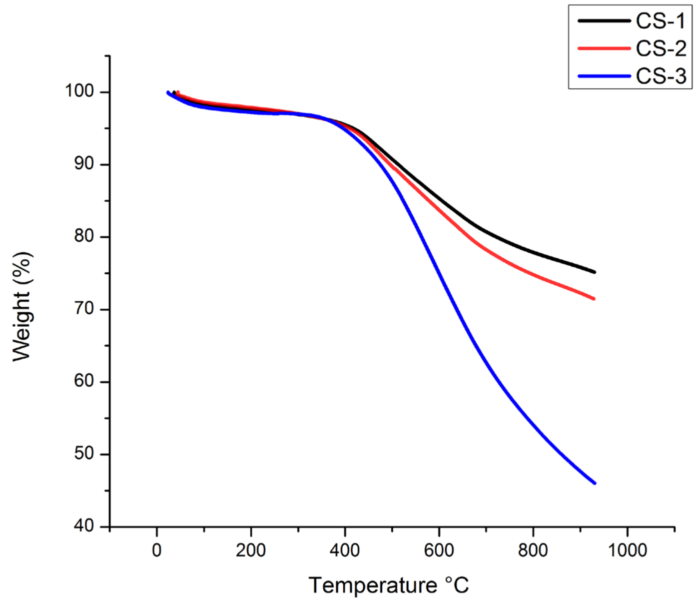
Table 3. Chemical analysis of coal spoils (wt%) by X-RF.

Constituents	CS-1 (wt%)		CS-2 (wt%)		CS-3 (wt%)	
	Direct XRF Analysis Data	Calculated Data on LOI	Direct XRF Analysis Data	Calculated Data on LOI	Direct XRF Analysis Data	Calculated Data on LOI
Na_2O	0.173	0.116	0.083	0.058	0.135	0.093
MgO	0.493	0.329	0.394	0.276	0.454	0.312
Al_2O_3	25.36	16.949	29.388	20.589	26.833	18.458
SiO_2	55.722	37.241	47.086	32.988	53.994	37.141
P_2O_5	0.706	0.472	0.823	0.577	0.711	0.489
SO_3	0.324	0.217	0.611	0.428	0.359	0.247
Cl	0.009	0.006	0.042	0.029	0.016	0.011
K_2O	1.71	1.143	1.641	1.150	1.466	1.008
CaO	1.679	1.122	2.326	1.630	1.842	1.267
TiO_2	3.144	2.101	3.116	2.183	2.799	1.925
Cr_2O_3	0.276	0.184	0.337	0.236	0.321	0.221
MnO	0.277	0.185	0.298	0.209	0.202	0.139
Fe_2O_3	9.589	6.409	13.033	9.131	10.348	7.118
Co_2O_3	0.018	0.012	0.023	0.016	0.011	0.008
NiO	0.059	0.039	0.075	0.053	0.068	0.047
CuO	0.017	0.011	0.039	0.027	0.021	0.014
ZnO	0.06	0.040	0.101	0.071	0.062	0.043
Ga_2O_3	0.007	0.005	-	-	0.006	0.004
Rb_2O	0.009	0.006	0.012	0.008	0.009	0.006
SrO	0.095	0.063	0.154	0.108	0.083	0.057
Y_2O_3	0.047	0.031	0.087	0.061	0.041	0.028
ZrO_2	0.103	0.069	0.134	0.094	0.078	0.054
BaO	0.096	0.064	0.151	0.106	0.122	0.084
PbO	0.019	0.013	0.045	0.032	0.014	0.010
ThO_2	0.004	0.003	-	-	0.004	0.003
LOI	-	33.167	-	29.940	-	31.213

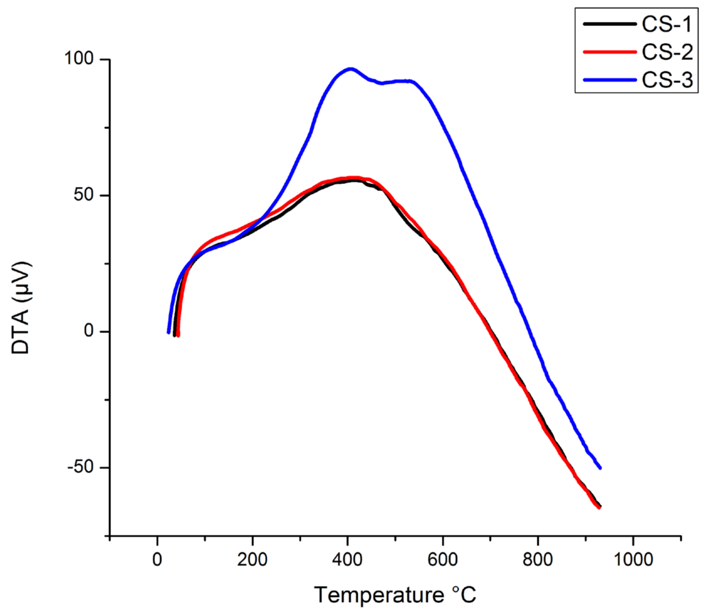
Cr, Co etc. were found in all categories of CS samples which indicate that, the trace heavy metals are released from the coal mine spoil into the environment.

3.5. Thermal Analysis of CS

The main minerals in the CS are graphite, quartz and kaolinite. Figure 5 shows the thermal analysis results of CS-1, CS-2 and CS-3. Figure 5(a) shows TGA graph of CS-1, CS-2 and CS-3 in which lowering of mass is evident by increasing temperature. CS-1, CS-2 and CS-3 gradually decreased their mass until 400˚C at



(a)



(b)

Figure 5. Thermal Analysis of CS-1, CS-2, and CS-3 (a) Thermogravimetric analysis; (b) Differential thermal analysis.

the same proportion, but at 400˚C to 900˚C CS-3 decreased it's mass rapidly than that of CS-2 and CS-1 indicating that the decomposition of CS-3 was faster than that of CS-2 and CS-1 in a order of CS-3 > CS-2 > CS-1. On the other hand, **Figure 5(b)**) shows DTA results of CS-1, CS-2 and CS-3. The thermal analysis results in **Figure 5(b)** show two exothermic peaks at 400˚C and 550˚C appeared in CS-3. These are related with the combustion of volatile matter and fixed carbon, respectively. The two exothermic peaks of CS-1 were found at 425˚C and 480˚C. A broad exothermic peak appeared at 410˚C for CS-2. No crystalline phase peak of kaolinite was appeared for CS-1, CS-2 and CS-3 till 950˚C. These results indicated that the combustion of volatile matter and fixed carbon of CS-03 occurred rapidly than that of CS-1 and CS-2.

4. Conclusion

Coal mining waste or coal spoil is an important issue for mine environmental protection. In this regard, characterization of mining waste is necessary for alternative utilization. In the present study, it was observed that Barapukuria coal mining waste mainly composed of high level carbonaceous materials. This material (CS) carries low sulfur content with high calorific value which is close to the coal of BCMCL. So, the CS of BCMCL can be used as a fuel in brick field and foundry industries as well as in thermal power plant for electricity generation. Further research in this field can be made in applied form to establish the economic prospect of coal spoil.

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