International Journal of Scientific & Engineering Research Volume 11, Issue 4, April-2020 1442
ISSN 2229-5518

Assessing the prospect of Coal Bed Methane in Khalashpir Coal Basin, Bangladesh

Hridita Ferdous, Wahida Akhtar

Abstract— This paper is a primary approach to make assessments on utilizing deep-seated coal by considering coal bed methane technology in the Khalashpir Coal Basin in Bangladesh. An estimation of gas content of each coal zones has been made from the available secondary data. Lifetime of a 240 MW power plant has also been calculated considering all the measured gas is used to generate electricity.

Index Terms— Coal Bed Methane, Bangladesh, Khalashpir Coal Basin, Alternative Energy, Hydraulic Frackturing, Methane Gas Content, Environmental Impacts.

———————————— ◆ ————————————

1 Introduction

THIS paper is a primary approach to make assessments on utilizing deep-seated coal by considering coal bed methane technology in the Khalashpir Coal Basin. An estimation of gas content of each coal zones has been made from the available secondary data. Lifetime of a 240 MW power plant has also been calculated considering all the measured gas is used to generate electricity.

The main objectives of this paper are to test the potential of Khalaspir coal basin from CBM perspective ant to contemplate environmental issues and possible mitigation.

2 Study Area

The coal basin under Pirganj upazila of Rangpur district lies in between latitudes $25^0$23′14″ and $25^0$30′0″ N and longitudes $89^0$09′12″ and $89^0$15′0″ E respectively in the survey of Bangladesh topographic sheet no.78 G/3. Coal is found only in the upper part (top 182.92m, 600ft) of the sequence in the basin and coal sequences are divided in 8 zones with numerous beds with average depth ranges between 265.974m to 404.336m and average thickness ranges between 11.355m to 1.399m (Imam, 2005).

Figure 1: Location of Khalashpir Coal Basin

Extensive Bituminous coal deposits occur in the Permian strata of the basin which can be potential in this respect where Coal Zone-II is thicker and widely developed. The volatile bituminous coal of coal Basin is suitable for CBM occurrence; however the depth of occurrence, thickness of coal seam, coal reserve and areal extent need to be considered to check its viability.

3 Analytical Results of Coal in Khalashpir Basin

Extensive Bituminous Gondowana coal deposits occur in the Permian strata of the Khalaspir basin. Due to widely spaced control points and lack of drill hole geophysical logging and palynological data, the correlation of different coal zone is tentative.

The studied coal bearing area covering three drill holes (GDH-45, 46 & 48) is only 2.52 square kilometers and the extension of probable coal bearing area is 12.26 square kilometers based on gravity anomaly map.

Coal is found only in the upper part (top 182.92m, 600ft) of the Gonwana sequence in the Khalaspir basin.

The coal sequences are divided in 8 zones with numerous beds. Each zone contains good quality, bright (vitrain) and dull (durain) coal fusain. In many places, the coal shows subtle bandings caused by alternations of bright and dull coal layers (up to 10cm). Fusain tends to occur as isolated lenses and thin layers (up to 10cm). The coal beds are underlain, overlain and grade laterally into and interbeds with carbonaceous shale and sandstone beds. The coal beds range in thickness from a few centimetres to 14.0 meters (GDH-45). Splitting and pinching out of the coal beds are observed. Vertical and lateral variations of the coal facies are present.

Analyses of the coal samples from different coal beds were performed in two different laboratories. M. Nazrul Islam of the Geological Survey of Bangladesh and Dr. Hal Gluskoter of US Geological Survey collected 41 samples from drill hole GDH-45 in 1989 for proximate and ultimate analyses. These samples were air tightly packed and sent by air to the Dickensons Laboratories Ltd. in USA for analysis.

The results of the analysis were interpreted and tabulated by M. Nazrul Islam and E.R Landis in the US Geological Survey in Denver. Later on in 1990, 43 samples from GDH-46 and 20 samples from GDH-47 were collected by the authors and sent to the chemical branch of Geological Survey of Bangladesh for proximate analysis (Md. Nazrul Islam).

Results of chemical analysis of representative samples from 8 coal zones were taken into consideration for this interpretation.

Moisture content: Moisture content of the samples varies from 0.36% (zone-VII) to 5.99% (zone-I). The average moisture content is 1.28%. Decrease of the percentage of moisture content with depth of the coal zone is observed. From coal zone 5 inward, the moisture content decreases almost to half (zone I-IV).

Ash: Ash content of the samples ranges from 50.51% (zone I) to 7.60% (zone I). The average ash content is 21.80 %. Among 84 samples from all zones, 61 sample show less than 25% ash, 16 show less than 15% ash. Low content of ash in some individual coal partings/small bed is also observed. In drill-hole GDH-46 average percentage of ash is found in coal zone IV but in GDH-45 low percentage of ash is found in coal zone I

Volatile matter: Volatile matter content of the samples ranges from 2.93% to 30%. The average is 22.86%. 31 samples contain less than 22%, 13 contain less than 14% and the rest above 22%. In GDH-46 the percentage of volatile matter is comparatively low in the top two zones in GDH-45 it is low in coal zone II and in GDH-47 it is comparatively higher in all the zones. On moisture and ash free basis of 41 samples from GDH-45, the volatile matter varies from 8.29% to 34.14%

Fixed Carbon: Fixed carbon content of the sample varies from 80.81% (zone-II) to 32.0% (zone-I). The average is 54.10%. 15 samples show less than 60% fixed carbon. Zone-I and zone-II has higher rate of fixed carbon amount comparing to the other zones. 41 samples from GDH-45 shows the range from 91.71% to 65.86% fixed carbon on moistrure and ash free basis.

Sulphur: sulphur content of the samples ranges from 0.24% to 3.15%. The average is 0.77%. Sulphur is more or less evenly distributed throughout the zones.

Heating Value: Maximum and minimum heating values vary from 13880 BTU (zone-I) to 7388 BTU/Ib (zone-I). The average heating value of the coal is 11264 BTU/Ib. Relatively lower heating value is observed in zone-I of GDH-46. Analysis of 41 samples from GDH-45 on moisture and ash free basis, the heating value varies from 14424 BTU to 15168 BTU/lb.

Coal Rank: From the analytical results, according to American Society for Testing and Material (ASTM) test method, most of the sample shows an apparent rank of medium volatile bituminous coal, and some of the samples have an apparent rank ranging from high volatile bituminous A to low volatile bituminous coal.

- *Hridita Ferdous has pursued Masters Degree program in Petroleum Geology in University of Dhaka, Bangladesh, E-mail: hridz0809@mail.com*
- *Wahida Akhtar has pursued Masters Degree program in Petroleum Geology in University of Dhaka, Bangladesh, E-mail: wakhtar19@gmail.com*

4 Estimation of Methane Gas Content in Khalashpir Coal Basin

Hypothetically the gas content can be measured by using Kim's equation which is stated below (Kim, 1977).

$$V = \frac{(100 - M - A)}{100} \times \frac{Vw}{Vd}[K(P)^N - (b \times T)]$$

Some secondary equations were used to evaluate the gas content from Kim's equation due to the limitations of direct data (Kim, 1977).

$$\frac{Vw}{Vd} = \frac{1}{(0.25 \times M + 1)}$$

$$K = 0.8 \times \frac{F.C}{V.M} + 5.6$$

$$N = 0.39 - 0.013 \times K \; [For\ Bituminous\ Coal]$$

$$T = Geothermal\ Gradient \times \frac{h}{100} + To$$

$$P = 0.096h$$

Where,
V= Volume of methane gas adsorbed (cc/g)
M= Moisture content (%)
A= Ash content (%)
V_w= Volume of gas adsorbed on wet coal (cc/g)
V_d= Volume of gas adsorbed on dry coal (cc/g)
K= Empirical values depending on the composition of coal.
P= Pressure at given depth
N= Empirical values depending on the composition of coal
b= Adsorption constant due to temperature change (cc/g/°C).
T= Temperature at given depth
F.C= Fixed carbon (%)
V.M= Volatile matter (%)
T_o= Ground temperature.
h= Depth

With the above derivation the gas content was found in cubic centimetre unit for each gram of coal which was then converted to cubic feet per ton. Then the total gas was calculated by multiplying with reserve. The measured gas content is tabulated in the result section.

5 Proposed Usage of the Coal Bed Methane: Electricity Generation

ISSN 2229-5518

One of the main objectives of the thesis paper is to use the CBM to meet up the energy crisis of the country. With this purpose, a 240 MW power plant is proposed for the usage of the total CBM in the Khalaspir basin.

5.1. Theoretical Assumptions

$$Running\ Duration\ of\ the\ power\ plant = \frac{Total\ Estimated\ Gas\ in\ Khalashpitr\ Basin}{Gas\ Consumed\ in\ 1\ Year}\ [arithmetic\ rule]$$

From the general conversion factors, energy content of methane gas can be calculated and from that duration of running of the power plant can be determined. For this required conversion factors are given below (Energy Content of Fuels, 2005).

Energy contents of Methane Gas = 1010 BTU/cf (Kopalek, 2014)

1 BTU = 1.055 KJ

1 KJ = 0.0002777777777778 KWh [As 1KWh= 3600s*1KJ/1s =3600 kJ]

1 KWh = 0.001MWh

When the energy is calculated n MW-h, it is converted to MW-yr.

5.2. Assumptions from Collected Data

$$Running\ Duration\ of\ the\ power\ plant = \frac{The\ measured\ value\ in\ MW-yr}{240\ MW}\ [arithmetic\ rule]$$

From the data collected from 2X120 MW Peaking Power Plant of Siddhirganj, Bangladesh in which electricity is generating through two units of 120 MW each simple cycle gas turbine, the value of gas consumption and net electricity generation was found for 12 months (1year). According to the Detail data of Siddhirganj 2X120 MW Peaking Power plant (Appendix-4), From the Siddhirganj 2X120 MW Peaking Power plant data, we get the amount of gas required per month as well as in 1 year in a single cycle gas turbine. So from this, the life time of the power plant was calculated.

6 Theoretical Findings

Hypothetically, gas content was measured with Kim's equation. From the data of moisture content, ash content, volatile matter and fixed carbon (Appendix 2, 3), the average value for each coal zone was calculated and tabulated below.

Table 1: Average moisture content, ash content, volatile matter & fixed carbon in %

Coal Zone/Seam	Average Moisture content, M (%)	Average Ash content, A (%)	Average Fixed Carbon, F.C (%)	Average Volatile Matter, V.M (%)
Zone-1	2.95333333	16.91	60.73333333	19.04333
Zone-2	2.15	19.59333333	60.09333333	18.16
Zone-3	1.32	24.91666667	51.34333333	24.42
Zone-4	1.46333333	17.68666667	56.47333333	24.31667
Zone-5	0.85666667	27.78666667	48.71	23.42
Zone-6	0.625	28.515	46.05	24.805
Zone-7	0.48	19.715	54.365	25.31
Zone-8	0.67	21.09	53.405	24.83

Then secondary calculations were made from the available data.

Table 2: Secondary Calculations for estimating the adsorbed methanegas content

Coal Zone/ Seam	Vw/ Vd	K	N	P	T (^{0}c)
Zone-1	0.575263663	8.15137406	0.28403214	25.08096	25.39638
Zone-2	0.650406504	8.24728341	0.28278532	27.25344	25.69057
Zone-3	0.751879699	7.28200928	0.29533388	29.59488	26.00764
Zone-4	0.732153752	7.45793009	0.29304691	31.20096	26.22513
Zone-5	0.823610158	7.26387703	0.2955696	34.44864	26.66492
Zone-6	0.864864865	7.08518444	0.2978926	35.53728	26.81234
Zone-7	0.892857143	7.31837218	0.29486116	36.72576	26.97328
Zone-8	0.856531049	7.32066049	0.29483141	37.82592	27.12226

For estimation of methane content, adsorption constant, b, was not derived directly due to lack of data. It was taken as average 0.14 cc/g/◦C from some previous works on different coal fields (Kim, 1977)

In Khalashpir area the highest temperature recorded is 32.9^0 Celsius in May and Lowest is 11^0 in January (Md. Nazrul Islam). Average temperature 22^0 Celsius was taken as ground temperature (T_o) which is not affected by surface heating and cooling though it is variable. As geothermal gradient is relatively higher in this area it was taken as 1.3 and the equation mentioned in chapter-4 was used to calculate T.

Table 3: Estimated Gas Volume in cc with proved coal reserve

Coal Zone/ Seam	Proved Reserve in Million Tons	V (cc/g)	V (cc/ton)	Gas Volume in cc
Zone-1	41.1	7.744922476	7026075.483	2.8877E+14

Zone-2	48.4	8.858243612	8036063.428	3.8895E+14
Zone-3	9.9	8.964107363	8132101.408	8.0508E+13
Zone-4	56.13	9.926005174	9004720.423	5.0543E+14
Zone-5	7.87	9.958573128	9034265.574	7.11E+13
Zone-6	9.55	10.27831567	9324331.131	8.9047E+13
Zone-7	7.38	12.3987755	11247979.92	8.301E+13
Zone-8	3.86	11.77408056	10681266.22	4.123E+13

Table 4: Estimated Gas Volume in Tcf with proved coal reserve

Coal Zone/ Seam	Proved Reserve in Million Tons	Gas Volume in cf	Gas Volume in Mcf	Gas Volume in Tcf
Zone-1	41.1	10197877374	10197877.37	0.010197877
Zone-2	48.4	13735480918	13735480.92	0.013735481
Zone-3	9.9	2843106528	2843106.528	0.002843107
Zone-4	56.13	17849268725	17849268.73	0.017849269
Zone-5	7.87	2510861385	2510861.385	0.002510861
Zone-6	9.55	3144678214	3144678.214	0.003144678
Zone-7	7.38	2931474000	2931474	0.002931474
Zone-8	3.86	1456012812	1456012.812	0.001456013
Total			**54668759.96**	**0.05466876**

The gas content has also been calculated for the probable reserve.

Table 5: Estimated Gas Volume in cc with probable coal reserve

Coal Zone/ Seam	Proved Reserve in Million Tons	V (cc/g)	V (cc/ton)	Gas Volume in cc
Zone-1	85.82	7.744922476	7026075.483	6.0298E+14
Zone-2	101.06	8.858243612	8036063.428	8.1212E+14
Zone-3	20.67	8.964107363	8132101.408	1.6809E+14
Zone-4	118.14	9.926005174	9004720.423	1.0638E+15
Zone-5	16.43	9.958573128	9034265.574	1.4843E+14
Zone-6	16.95	10.27831567	9324331.131	1.5805E+14
Zone-7	19.95	12.3987755	11247979.92	2.244E+14
Zone-8	15.4	11.77408056	10681266.22	1.6449E+14

Table 6: Estimated Gas Volume in Tcf with probable coal reserve

Coal Zone/ Seam	Probable Reserve in Million Tons	Gas Volume in cf	Gas Volume in Mcf	Gas Volume in Tcf
Zone-1	85.82	2.1294E+10	21293961.95	0.021293962
Zone-2	101.06	2.868E+10	28679911.19	0.028679911
Zone-3	20.67	5936061812	5936061.812	0.005936062
Zone-4	118.14	3.7568E+10	37568369.98	0.03756837
Zone-5	16.43	5241861825	5241861.825	0.005241862
Zone-6	16.95	5581392223	5581392.223	0.005581392
Zone-7	19.95	7924513049	7924513.049	0.007924513
Zone-8	15.4	5808963030	5808963.03	0.005808963
Total			**118035035.1**	**0.118035035**

With the resultant adsorbed gas value running duration for a 240 MW power plant was calculated.

Table 7: Energy Content Calculation with Proved Coal Reserve (Theoretical)

Coal Zone/ Seam	Gas Volume in cf	Energy Content in BTU	Energy Content in KJ	Energy Content in KW-H
Zone-1	10197877374	1.02999E+13	1.08663E+13	3018430066
Zone-2	13735480918	1.38728E+13	1.46358E+13	4065511581
Zone-3	2843106528	2.87154E+12	3.02947E+12	841520044.8
Zone-4	17849268725	1.80278E+13	1.90193E+13	5283135636
Zone-5	2510861385	2.53597E+12	2.67545E+12	743180097
Zone-6	3144678214	3.17612E+12	3.35081E+12	930781075.3
Zone-7	2931474000	2.96079E+12	3.12363E+12	867675589.1
Zone-8	1456012812	1.47057E+12	1.55145E+12	430959569.8

Now with the following conversion factors, running duration of a 240 MW power plant was calculated
1 KW-h= 0.001 MW-H
1 MW-H= 1/ (365X24) MW-Yr

Table 8: Running Time calculation for a 240 MW power plant with proved coal reserve (theoretical)

Coal Zone/	Energy Content	Energy Content	Total Energy in	Running Time in

<table>
<tr><th>Seam</th><th>in KW-H</th><th>in MW-H</th><th>MW-Yr</th><th>Year</th></tr>
<tr><td>Zone-1</td><td>3018430066</td><td>3018430.066</td><td rowspan="8">1847.168226</td><td rowspan="8">7.696534275</td></tr>
<tr><td>Zone-2</td><td>4065511581</td><td>4065511.581</td></tr>
<tr><td>Zone-3</td><td>841520044.8</td><td>841520.0448</td></tr>
<tr><td>Zone-4</td><td>5283135636</td><td>5283135.636</td></tr>
<tr><td>Zone-5</td><td>743180097</td><td>743180.097</td></tr>
<tr><td>Zone-6</td><td>930781075.3</td><td>930781.0753</td></tr>
<tr><td>Zone-7</td><td>867675589.1</td><td>867675.5891</td></tr>
<tr><td>Zone-8</td><td>430959569.8</td><td>430959.5698</td></tr>
</table>

Similar theoretical calculations were made to calculate the running duration of a 240 MW power plant with *probable reserve* and the running time was found as *16.61754709 Year.*

Again, with Siddhirganj 2×120 MW Peaking Power plant data (Appendix-4), running duration was estimated.

Table 9: Running Time calculation for a 240 MW power plant with proved coal reserve with Siddhirganj 2×120 Peaking Power plant data

Total Gas Consumed ina year, Nm3	Net Electricity Generation in a year, KWh	Total Gas from Proved Reserve in Cf	Total Gas from Proved Reserve in Nm3	Running Time in Year
194121607.1	508936680	54668759957	1548044342	7.97461 1199

Similar calculations with Siddhirganj 2×120 MW Peaking Power plant data were made to calculate the running duration of a 240 MW power plant with *probable reserve* and the running time was found as *17.21794 Year.*

7 Environmental Impacts associated with CBM production

There are substantial environmental risks in developing CBM resources. CBM production might end in pollution from pressing of exhaust gases, gas discharge, dust, and also the operation of pumps, compressors, and alternative machinery generates sound pollution. The chief environmental considerations from CBM production, however, arise from the necessity to dispose massive volumes of produced water, from the potential for the uncontrolled unharness of gas from the coal reservoir to shallow groundwater, from the potential for drawdown of shallow groundwater, and from the potential for certain well completion technologies to have an effect on shallow groundwater.

7.1. Spontaneous Combustion of Dewatered Coalbeds

Spontaneous combustion is Associate in nursing chemical reaction reaction that happens without external heat supply. The CBM extraction process changes the internal heat profile of the material leading to a rise in temperature which can gradually lead to open flame and burning of the material. . As the Khalashpir coalfield is situated in relatively high temperature area along with greater geothermal gradient, precaution must be taken for safe extraction of coalbed methane. (Huw Phillips)

7.2. Compaction/Subsidence

When water, a part of the fabric of a geologic formation, is removed from the rock for CBM extraction process, the pore spaces in rock are left open, and the rock might collapse. Continuous removal of water from coal seams depletes water and may lower boreholes eventually and surface water flows (streams and rivers). The consequences of the subsidence have enclosed the rupturing of utility lines (gas, sewage, and water, electric), collapse of buildings, and harm to roads. As for khalashpir space this case should be thought of and necessary measures should be taken.

7.3 Water Contamination

When hydraulic fracturing method is applied for CBM extraction, surface water may also get contaminated through spillage and improperly designed and maintained waste pits, and water may be contaminated if the fluid is in a position to flee the formation being broken or by made water. Generally less than half the produced water used for fracturing the formation is recovered.

7.4. Noise

The production of CBM requires the operation of well-site equipment. Although the noise generated by well-site equipment is often a low hum, the humming can be an aggravation to those living nearby. To take CBM to market, the gas must be compressed. Compressors are by far the noisiest aspect of CBM development. Depending on wind direction, the roar of a field compressor can be heard three to four miles from the site. Near the compressor stations, people need to shout to make them heard over the sound of the engines.
From exploration through site abandonment, noise is generated by truck traffic, heavy equipment, seismic explosions, drilling rigs, motors that power pumps, and gas compressors. The noise from all of the equipment may be a frustration for landowners. The constant noise from pumps and compressors, however, can greatly affect a landowner's quality of life, and have negative impacts on livestock and wildlife. (J. Berton Fisher Exponent)

7.5 Earthquake Risk

When hydraulic fracturing process is applied for extracting coal bed methane gas, it sometimes causes induced seismicity

ISSN 2229-5518

or earthquakes. The magnitude of those events is typically too small to be detected at the surface, although tremors attributed to fluid injection into disposal wells are large enough to possess often been felt by people, and to possess caused property damage and possibly injuries. Micro-seismic events are often used to map the horizontal and vertical extent of the fracturing.

8. Recommendations

CBM is a very good resource of alternative energy. The prospect of Khalashpir coal basin in this perspective are moderately potential, however, detail study is required to be utterly sure.

For extraxcting adsorbed methane gas, in-situ coal pillars can be constructed and gas can be extracted from specific area of underground coal to avoid subsidence. The area of in-situ pillars and production zone should be constructed in a way so that maximum production can be done along with avoiding subsidence.

If fluid is injected for hydraulic fracturing , fluid propagation must be measured so that the injected fluid do not get highly away from the capture zone and the casing of well must be done carefully to prevent the leakage of methane gas to the ground water.

The locations chosen for compressor stations and other noisy equipment for drilling can be selected to minimize their impact on the acoustic environment.

The drilling well and extraction process must be planned in a way so there is minimum chance for occurring environmental problems.

9. Conclusion

The Khalashpir coal field, with 184.19 million tons of coal (Md. Aliur Rahman, 2017), has moderate potential for CBM extraction. The CBM technology has established in coal fields in all around the world where either coal depth are not viable for conventional coal mining or the thickness of the coal is very high to contain economically viable adsorb gas. The depth and thickness is an important concern in CBM issue, however, CBM has been extracted in many parts of the world from shallower depth and fewer thicknesses. So for Khalashpir coal basin the main concern for CBM is the adsorbed gas content relative to economic viability. From this hypothetical study the followings statements can be concluded.

- The volume of adsorbed gas has been estimated using Kim's equation which is an indirect method for gas estimation. The volume of gas has been measured for each zone of coal using the analysed data of Geological Survey of Bangladesh. The total volume of the adsorbed gas of Khalashpir coal basin is estimated to be 0.05466876 Tcf from proved reserve and 0.118035035 Tcf from probable coal reserve.
- If the adsorbed methane in coal is extracted, the degasified coals will produce minimum mining risks for future coal mining in Khalashpir coal basin
- The utilization of the methane gas has primarily been suggested for electricity generation and the running duration of a 240 MW power plant is estimated for simple-cycle gas turbine. With the total estimated adsorbed gas volume of Khalashpir coal basin a 240 MW electricity generation simple-cycled power plant can run for approximately 7.5 years. From this theoretical finding this aspect of using the adsorbed methane gas shall not be economically feasible. However, this amount of gas can be added to an already established power plant as an additional source to extend the running time subjected to economic and environmental viability. Running time of 240 MW power plant has also been calculated with probable reserve where it shows around 17 years of duration, so this probable resource is needs prime attention in the hunt for this alternative energy.
- The environmental issues related to CBM technology is of great concern and possible mitigation must be done for environmental issues that might occur while extracting methane from underground coal zones.

Despite of the fact that the economic viability of CBM extraction is of great concern, the hypothetical gas content estimation suggests to go for CBM extraction in this coal field. Due to lack of primary data the accurate gas content could not be measured but the hypothetical presentation indicates that detail investigation is required and Khalashpir coal basin must be focused with great importance for this alternative energy resource.

References

[1] Energy Content of Fuels. ENVIR215, 2005

[2] '*Techno-economic Feasibility Study of Khalashpir Coal Mine Project, Dhaka, Banglades'* China Jinan Mining Development Corporation, 2006

[3] Imam, M. B. *Energy Resources of Bangladesh*. University Grants Commission of Bangladesh, 2005

[4] Kim, A. G. '*Estimating Methane Content of Bituminous CoalBed from Adsorption Data'*, Bureau of Mines, United Stated Department of the Interior., 1977

[5] Kopalek, M. "*Today in Energy. Retrieved from U.S Energy Information Administration'*, (URL Link: https://www.eia.gov/todayinenergy/detail.php?id=18371, accessded on 14 March, 2020), (14 October, 2014).

[6] Md. Aliur Rahman, C. Q. '*Coal Reserve Estimation and Selection of Mining Method in Khalashpir Coal Field, Rangpur, Bangladesh*', 'International Journal of Emerging Technology and Advanced Engineering',

2017

[7] Md. Nazrul Islam, M. N.-u.-I. (n.d.). *'Geology of Khalshpir Coal Basin*. Geological Survey of Bangladesh.'

[8] J. Berton Fisher Exponent, I. T. (n.d.). '*Environmental Issues and Challanges in Coal Bed Methane Production.*'

[9] Huw Phillips, S. U. (n.d.). '*Prevention and control of Spntaneous Combustion.*' 'Coaltech Research Association'

APPENDIX-1

Coal Seam	Average Thickness(m)	Average Depth(m)
Coal Seam-I	8.303	261.26
Coal Seam-II	9.778	283.89
Coal Seam-III	2.00	308.28
Coal Seam-IV	11.43	325.01
Coal Seam-V	1.59	358.84
Coal Seam-VI	1.93	370.18
Coal Seam-VII	1.49	382.56
Coal Seam-VIII	0.78	394.02

Coal Seam	Proved Reserve (million tons)	Probable Reserve (million tons)
Coal Seam-I	41.10	85.82
Coal Seam-II	48.40	101.06
Coal Seam-III	9.90	20.67
Coal Seam-IV	56.13	118.14
Coal Seam-V	7.87	16.43
Coal Seam-VI	9.55	16.95
Coal Seam-VII	7.38	19.95
Coal Seam-VIII	3.86	15.40
Total	**184.19**	**385.53**

APPENDIX-2

Bore Hole	Coal Zones/Seams	Depth, m	Moisture Content (%)	Ash Content (%)
GDH-45	Zone-1	284.95	2.66	17.2
	Zone-2	352.74	2.91	21
	Zone-3	369	1.82	21.23
	Zone-4	415.7	1.98	23.66
	Zone-5	436.96	1.5	31.59
GDH-46	Zone-1	318.6	5.1	22.66
	Zone-2	341.46	2.65	20.25
	Zone-3	364.02	1.24	23.59
	Zone-4	367.02	0.99	13.04
	Zone-5	398.4	0.57	23.64
	Zone-6	398.4	0.61	26.07
	Zone-7	407.32	0.36	16.48
	Zone-8	425.3	0.66	22.13
GDH-47	Zone-1	257.16	1.1	10.87
	Zone-2	269.51	0.89	17.53
	Zone-3	281.1	0.9	29.93
	Zone-4	288.49	1.42	16.36
	Zone-5	310.1	0.5	28.13
	Zone-6	317.1	0.64	30.96
	Zone-7	322.4	0.6	22.95
	Zone--8	378.2	0.68	20.05

APPENDIX-3

Bore Hole	Coal Zones/Seams	Fixed Carbon (%)	Volatile Matter (%)
GDH-45	Zone-1	55.87	23.22
	Zone-2	57.09	19
	Zone-3	54.09	28.86
	Zone-4	53.41	20.93
	Zone-5	47.67	19.24
GDH-46	Zone-1	65.34	6.89
	Zone-2	68.91	8.18
	Zone-3	55.07	20.1
	Zone-4	60.04	25.56
	Zone-5	53.52	22.37
	Zone-6	51.16	22.15
	Zone-7	58.14	24.66
	Zone-8	54.52	22.68
GDH-47	Zone-1	60.99	27.02
	Zone-2	54.28	27.3
	Zone-3	44.87	24.3
	Zone-4	55.97	26.46
	Zone-5	44.94	28.65
	Zone-6	40.94	27.46
	Zone-7	50.59	25.96
	Zone--8	52.29	26.98

APPENDIX-4

Siddhirganj 2×120 MW Peaking Power plant data of year 2014-2015

Months	Total Gas Consumption, Nm3	Total Gross Generation	Net generation, KWh
14-Jul	4642104.00	4684303.00	11998320.00
14-Aug	11508976.00	11551206.00	31933248.00
14-Sep	1718280.00	1760541.00	5113464.00
14-Oct	7353461.13	7395752.13	19461840.00
14-Nov	14257000.00	14299322.00	39786504.00
14-Dec	10712325.17	10754677.17	28025184.00
15-Jan	24774763.00	24816782.00	65546232.00
15-Feb	22099291.09	22141341.09	57694584.00
15-Mar	25245430.56	25287508.56	67285200.00
15-Apr	20328414.38	20370523.38	50216712.00
15-May	26357580.21	26399719.21	66011616.00
15-Jun	25123981.55	25166151.55	65863776.00
Total	194121607.09	194,627,827.09	508936680.00