*International Conference on Mechanical, Industrial and Materials Engineering 2017 (ICMIME2017)*
*28-30 December, 2017, RUET, Rajshahi, Bangladesh*

***Paper ID: ET-146***

# Prospects of Underground Coal Gasification (UCG) Process in Khalaspir Coal Fields, NW, Bangladesh

Md. Lotifuzzaman[1], Md. Kamrul Islam[2]

[1]Dept. of Petroleum and Mining Engineering, Jessore University of Science & Technology
[2]Assistant professor, Dept. of Petroleum and Mining Engineering, Jessore University of Science & Technology
*E-mail: [1]ronypme100824@gmail.com, [2]ranapme@gmail.com*

## *Abstract*

*The Khalaspir coal field is located in the north western part of Bangladesh which is confirmed by the three drill-holes among the four done by GSB with a proved area 2.52 $km^2$ and probable area 12.26 $km^2$. The coal basin is north-west to south-east elongated fault bounded basin having eight coal seams with an average composite thickness 50m and proved and probable coal reserve is about 142.92 million tons and 685 million tons respectively with a depth ranging from 257.16m to 483.81m from the surface. The coal is ranked as medium volatile bituminous low sulfur coal with 21.80% ash content. The possibility of Underground coal gasification (UCG) method for coal extraction as syngas provides the best alternative for long-wall mining system by removing the hazards like $CH_4$, CO, $CO_2$ emission, subsidence and others. Our study considers geological, hydrological, depositional, proximate analysis and temperature based data of this coal field.*

Keywords: Coal Basin, Seams, Reserve, Depth, UCG.

## 1. Introduction:

The Khalaspir coal Mine is located on a sub-cropped asymmetrical synclinal deposit Gondwana coal of Permian age (Review of “Techno-Economic Feasibility Study” Khalaspir Coal Mine.2009), a structure first indicated by a negative gravity anomaly in oil and gas exploration. Exploration for the deposit was initiated by the Geological Survey of Bangladesh (GSB), with four Geological drill holes. Among the four drill hole, three drill holes confirmed the existence of coal deposit having a sequence of upto eight coal seams, some of which had the potential for economic exploration. The most thin and laterally extensive seams of the deposit is designed as seam i, ii and iv with an average thickness 16.95m, 9.93m and 6.96m respectively (Islam,M.N. 1992) and IMC focused on these primary target for multislicing by longwall mining method. The stratigraphic and structure of the basin is now known in some detail, both from borehole and seismic survey data. To date however no analytical investigation has been undertaken on the potential of UCG in the basin. UCG is the modern technology of extracting the coal by converting into syngas or UCG gas. The economic successes of UCG process in Soviet Union, USA, Canada, China, Poland, Australia and India remarkable. In Bangladesh, the only non-renewable energy resource is natural gas and currently faced a major indigenous situation. The proven and probable resource, within 22 gas fields in the country total is estimated at 804.5Gm3 of which 580.7Gm3 is considered recoverable. Approximately 144.5Gm3 has been consumed to June 2003 leaving a remaining recoverable reserve of 436.2Gm3.Gas production is increased for the demand of growth population and to be exhausted in 15 to 20 years (National Energy Policy-2004). So, it is necessary to investment in the research and development of alternating energy source. In this respect, the investigation of UCG possibility in existing coal field like Jamalgonj, Barapukuria, Phulbari, Khalaspir,Dighipara,Nawabgon and Dangapara basin can contribute to the increasing demands of the country. The Khalaspir coal mine have an estimated reserve is about 142.92 million tons (eight coal seams). According to FS and IMC, using Longwall multislicing method only 4 million tons per year can be extracted. The longwall mining method is now practiced in Barapukuria coal mine and recovery rate is only 9% (Islam, M.R, 2008.). As the basin configuration and coal deposit of Barapukuria coal field and Khalaspir coal field mostly similar, the production rate of Khalaspir coal field may be low as Barapukuria coal field due to various potential hazards like methane emission, co-emission, spontaneous combustion, air temperatures, subsidence, sliding, and dust problem. However, Imam Et.al (2002) and Islam, M.R (2008) investigated the CBM potential of the Jamalgonj and Barapukuria coal deposit respectively, but UCG potentiality cannot be investigated. This study examines the possibility of UCG method of exploitation on Khalaspir deposit including a review of previous exploration and evaluation history of the geological structure, coal geology, coal analytical data, hydrological data, reserves, and other parameters. The UCG technology has the potential to make a significant contribution to the future energy demands of Bangladesh and could provide an economically attractive alternative to relatively environmentally unfriendly surface and underground coal mining.

## 2. Khalaspir Coal Field:

The Khalaspir basin is evaluated from northwest to southeast direction. There found three prominent gravity high, the Purging high (-22.2m. gal), the Bhendabari high (-32.2m gal), and the Bhaduria high (-30m gal) to encompass the basin in the northeast, north and south – southeast respectively. The drilling data indicates the existence of a major fault in the north – northeast side (GDH -46) with NNW- SSE alignment. It is also a prominent fault in the Gondwana basin and controls the basin characteristics. The fault length is not detected due to the lack of data but correlating the data from drill hole GDH -46 and 48, it may be about 150m.

### 2.1 Location, extent and topography:

The Khalaspir coal basin is sited under Purging Upazila of Rangpure District and located between latitudes 25° 23` 14`` and 25° 30` 0``N and longitudes 89°09`12``and 89° 15` 0`` E respectively in the Survey of Bangladesh topographic sheet No. 78 G/3. The basin area contains approximately 12.26 $km^2$ within a wide flood plain area having minor undulations covered by brained clay residuum and flood plain deposits. Green paddy land is seen miles after miles with village on artificially raised grounds. The regional slope is indicated north to south and the average elevation of the area is 25m above the mean sea level.

### 2.2 Stratigraphy of Khalaspir:

The stratigraphy description of permian Gondwana basin whish is located in the North Western part of the country was given by various authors (Ahmed and Zaher, 1963, 1965; Islam et al, 1987;Alam et al ,1990; Zaher and Islam, 1975 ). Alam et al ( 1990 ) published the detail description of the lithology and depositional models of the Barapukuria Coal Basin.The Khalashpir basin area is moderately plain area which covered by barind clay residuum and alluvium. On the basis of the four drill hole data ,the sedimentary succession of the basin are generalized in table-1.

Table-1: Generalised Stratigraphic Succession of Khalashpir Basin (Islam, M.N,1992)

| Age | Group / Formation | Lithology | Maximum Thickness (m ) |
|---|---|---|---|
| Holocene | Alluvium | Grey sand and Silty clay. | 4.26 |
| Pleistocene | Barind clay residuum | Uncomformity<br>Yellowish grey silty clay. | 6.10 |
| Pliocene | Dupitila Formation | Uncomformity<br>Grey to yellowish grey sandstone, pebbly sand stones with uncommon mudstone. | 162.12 |
| Miocene | Surma group | Uncomformity<br>Grey to dark greymudstone, sandstone and pebbly sandstone. | 184.14 |
| Permian | Gondwana Group | Uncomformity<br>Felspathic sandstone, carbonaceous sandstone, carbonaceous shale, siltstone, mudstone, coal,and conglomerate.<br>Base Not Seen | 814.93 + |

The Gondwana group contains the strata ranging from Upper Carboniferous to lower cretaceous in age (Riemann, K.U, 1993). But still some confusion exists about the age and subdivision of the Gondwana system. However some geologist and paleo-botanists divided the system into the three major parts namely Lower Gondwana, Middle Gondwana and Upper Gondwana. The Gondwana group does not contain any particular formation but mainly composed of hard compact medium to course grain, often pebbly sandstones interbedded with some conglomerates, carbonaceous shale and coal. It contains many facies and coal with sandstone facies is one of them and encountered in drill holes GDH- 45, 46 and 47 from the depthof 484.75m to 282.92m, 404.87m to 316.46m and 325.91m to 256.70m respectively. Maximum thicknest coal found in the central part of the basin and seems to be gradually thinned out in the northern and western part (GDH-46 and47). The sandstone show upward fining and downward coarse sequence.The surma group lies above the Gondwana group with a sequence of alternating sandstone and shale bed. This group is some time called Jamalganj formation and have a average thickness about 184m and overlies the gondwana group with an unconformity. The Dupitila formation is a shale dominating unit and located just above the jamalganj formation. In different drill holes, this formation shows extra ordinary variation.. The Dupitila formation is a sand dominating unit and located just above the jamalganj formation. In different drill holes, this formation shows exta ordinary variation.

## 2.3 Coal of Khalaspir Basin:

Coal is composed primarily of carbon along with variable quantities of other elements like hydrogen, sulfur, oxygen, and nitrogen. In the Khalaspir basin, coal is only found in the upper part of the Gondwana sequence (top 182.92m). The coal sequence of this basin according to the drill hole data are classified into eight zones with a lots of coal bed. Each zone contains good, bright and dull coal with fusain. These coals shows banding of bright and dull coal layer up to 10cm. the coal beds are underlain , overlain and greatly lateral into and inter beds with carbonaceous shale and sandstone beds. The thickness of these coal beds are ranging from few centimeters to 14m (GDH_45) (Islam M.N, 1993).

Table-2: Summarized depths of coal seams with beds and thickness in respect to GDH- 45, 46 and 47.

| No. of Coal Seam | Depths (m) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GDH-45 | | | | GDH-46 | | | | GDH-47 | | | |
| | No. of Beds | From | To | Thickness | No. of beds | From | To | Thickness | No. of beds | From | To | Thickness |
| **i.** | 6 | 284.95 | 321.11 | 31.84 | 2 | 318.60 | 332.00 | 12.79 | 1 | 263.16 | 263.18 | 6.02 |
| **ii.** | 1 | 352 | 365.01 | 12.27 | 6 | 341.46 | 355.61 | 10.48 | 3 | 269.51 | 277.58 | 6.81 |
| **iii.** | 1 | 369 | 369.01 | .81 | 1 | 364.02 | 364.94 | .92 | 1 | 281.10 | 283.0 | 1.90 |
| **iv.** | 5 | 415.70 | 425.12 | 6.91 | 3 | 367.98 | 378.20 | 8.72 | 3 | 288.49 | 294.51 | 4.1 |
| **v.** | 1 | 436 | 438.49 | 1.53 | 2 | 382.77 | 400 | 3.43 | 3 | 310.10 | 314.02 | 1.88 |
| **vi.** | 2 | 449.28 | 450.88 | 1.35 | 3 | 398.40 | 404.44 | 2.63 | 1 | 317.15 | 317.89 | .74 |
| **vii.** | 1 | 461.89 | 464.33 | 2.44 | 2 | 407.32 | 414.17 | 1.98 | 2 | 319.20 | 322.71 | .77 |
| **viii.** | 2 | 481.31 | 482.93 | 1.54 | 3 | 425.26 | 427.76 | 2.12 | 2 | 323.73 | 378.51 | 1.27 |

Table-3: Coal reserves of the Khalaspir Basin (Islam M.N, 1992)

| Coal zone | Area | | Average thickness (m) | Proved reserved (million tons) | | Total Probable reserves |
|---|---|---|---|---|---|---|
| | Proved area | Probable area | | Individual reserves | Total Reserves | |
| **i.** | | | 16.9 | 56.3 | | |
| **ii.** | | | 9.9 | 33.0 | | |
| **iii.** | | | 1.2 | 4 | | |
| **iv.** | | | 6.9 | 23.1 | | |
| **v.** | 2.52 sq.km | 12.26 sq.km | 2.7 | 7.5 | 142 | 685 |
| **vi.** | | | 2.6 | 8.8 | | |
| **vii.** | | | 1.6 | 5.5 | | |
| **viii.** | | | 1.3 | 4.3 | | |

However the coal samples from different coal beds are analyzed and the results of analysis were interpreted and tabulated by M. Nazrul Islam and E. R Landis in the US geological Survey at Denver. Later on in 1990, 43 samples from GDH- 46 and 20 samples from GDH- 47 were collected by the authors of Geology of the

Khalaspir Coal basin Book and sent to the chemical dept. of Geological Survey of Bangladesh for proximate analysis.

Table-4: Summarized analytical results (proximate) of coal in drill holes GDH- 45,46 & 47 (Islam M.N 1993)

| No. of coal seam | Moisture content % | Ash% | Volatile matter % | Fixed Carbon% | Total Sulfur% | Heating Value Btu/Ib |
|---|---|---|---|---|---|---|
| **i.** | 2.63 | 18.04 | 21.82 | 57.45 | 0.84 | 11753 |
| **ii.** | 2.29 | 18.38 | 17.40 | 60.47 | 0.96 | 11505 |
| **iii.** | 1.32 | 24.92 | 40.42 | 51.34 | 0.69 | 10782 |
| **iv.** | 1.43 | 17.51 | 24.04 | 57.02 | 0.90 | 11757 |
| **v.** | 0.79 | 26.75 | 22.66 | 49.81 | 0.74 | 10725 |
| **vi.** | 0.62 | 27.30 | 23.48 | 48.60 | 0.65 | 10436 |
| **vii.** | 0.48 | 19.90 | 25.31 | 54.32 | 0.87 | 11580 |
| **viii.** | 0.67 | 21.61 | 23.76 | 53.97 | 0.51 | 11575 |
| **Average result value** | 1.28 | 21.80 | 22.86 | 54.10 | .77 | 11264 |

## 3. Underground Coal Gasification Process:

Underground coal gasification is an industrial process that converts the coal into UGC or syngas. It is an in-situ gasification process employed in deeper coal deposit which is not extracted by general mining method. The Underground coal gasification process usually contain two types of well such as Injection well and Production well. The injection well is used to inject the compressed air or oxygen or steam mixture into the target coal seam. Sometimes this well is also used to ignition purpose. After ignition of coal seam it creates a combustion chamber. In order to avoid potential environmental concerns the reactor cavity is operated at less than hydrostatic pressure which bring water into the gasification reaction in-situ. When combustion occurred the following reaction are formed

1. Oxidation/ combustion
   $2C + O_2 \longrightarrow 2CO$
   $C + O_2 \longrightarrow CO_2$
2. Gasification
   $C + H_2O \longrightarrow CO + H_2$
   $C + 2H_2O \longrightarrow CO_2 + 2H_2$
   $CO + H_2O \longrightarrow CO_2 + H_2$
   $C + 2H_2 \longrightarrow CH_2$

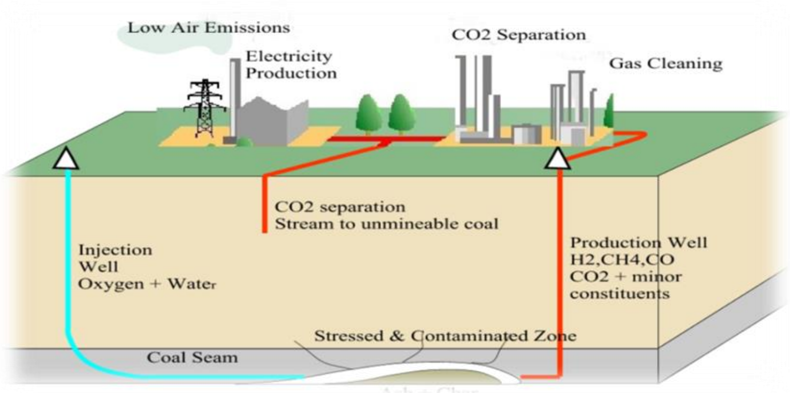


Figure-1: Basic Concept of Underground Coal Gasification (UCG Engineering, Ltd., 2006)

A successful UGC operation depends on the natural permeability of the coal seam to transit gases to and from the combustion zone or on enhanced permeability created through reversed combustion in seam channel or hydro fracturing. After coal burning and releasing the gases from the coal, the gases are lifted up through a well is called production well. The well design considers two factors such as coal deposit structure and coal bed dip angle.it may be single horizontal and vertical well , paired vertical well and minor complex well geometries, the number of well required is generally depends on deposit area reserves and required production rate.

A wide variety of coals are amenable to the UCG process. Coal grades from lignite to bituminous are successfully gasified using this method. The prediction for UCG acceptability depends on some key factors. According to Andrew Beatho f CSIRO Exploration and Mining, the prediction factors are coal seam depth must be ranging between 100 – 600 m (330- 1970ft), the coal bed thickness must be above 5m (16ft ), ash content must be less than 60 %, minimum discontinuity and isolation from valued aquifers. Later on Peter Sallans of Liberty Resources limited mentioned some factors as like as Andrew Beatho and these are Coal seam depth must be ranging between 100 – 1400 m (330- 4590ft), The coal bed thickness must be above 3m (9.8ft ). Kendra

L. Zamzow of Center of Science in Public Participation defines some factors for predicting UCG of a coal seam on his Underground Coal Gasification thesis paper. These factors are

a. Geologic conditions that preventing subsidence due to UCG process
   - At least 200m below from surface
   - Structural integrity of host rock
   - Geophysical modeling of temperature / pressure stress on fractures

b. Siting to prevent contaminant migration due to UCG process
   - Impermeable cap rock must be present above the coal deposit.
   - A distance at least 25 times the depth of coal seam between the seam and aquifer,
   - A minimum distance of coal seam about1.8 km from the rivers or lakes.
   - A minimum distance of coal seam about .8 km from the major fault.
   - Seams should be thick and widely separated.

## 4. Discussion:

The Khalaspir basin lies on the Precambrian basement on the stable platform in the north western part of Bengal basin with largest axis in the northwest – southeast direction. The basin is bounded by major normal fault forming graven. This fault may the major fault in the Gondwana basin. The throw of the fault cannot be determined due to the lack of the data. But by the correlation data of drill hole GDH-46 and 48, it appears to be about 150m (Islam, M.N, 1992). later on 2D and surface seismic survey were undertaken over the prospect in 2005 and seven normal faults have been identified , trending generally sub parallel to the northwest to southeast synclinal axis. The three largest faults in the Feasibility Study are interpreted with maximum vertical displacement and these types of fault can be overcome with UCG process. To adjust for fault discontinuities in the UCG prospect drilling equipment has the capacity to contain eyes that see the geologic structure ahead of the drill bit ,the drill can be then adjusted as necessary (Sury et al 2004, in Shafirovich et al 2008).Generally coal contains water and combustion cavities are expected to have water flux into them. But much water will reduce the methane content in the gas and heating value. For this reason, in the UCG process it is preferable to use coal with low moisture content and with no overlying aquifer within 25 times height of the seam. It is also noticed that there is not allow any river and lakes within 1.6 km. From the analytical result (proximate) of the Khalaspir Coal sample, the average moisture content is about 1.28% and it is very low and suit to the UCG process. In Rangpur and Dinajpur areas, the coal deposits are covered unconformable at the top by 100 to 200m thick loose to poorly consolidated water bearing sandy layer (Imam, B. 2013). According to the stratigraphy of the Khalaspir coal basin, this layer belongs to the Dupitila formation and its thickness is about 162.14m (Table-1). In the feasibility study report it is quoted that Dupitila formation lied just above the coal deposit consider as the major aquifer and the Gondwana formation below as a significant second aquifer without providing any hydraulic data on the latter. IMC considers that the Dupitila formation is a regional aquifer. The low of the Dupitila formation is Surma groups have an average thickness is about 184m. This formation is mainly composed of alternating sandstone and shale beds. According to the IMC, the Surma group has apparently significantly lower in hydraulic conductivities and should not be addressed as aquifers to coal deposit. Again, the drainage and water supply system of the target basin area is surface water and annual rainfall. In this area the major surface water source are the karatoyariver and Akhira lakes. The Karatoya River is about 13km north-west and Akhira is about 7 km north east from the basin. According to the above hydrological characteristics of Khalaspir basin, the coal deposit is suitable with the UCG process. The low temperature can cause the pathway between wells to plug. But high temperature reduces the efficiency of the gasification process and the heat value of the final gas. The UCG process burns coal under heat ranging from 10000- 1600°C and pressure with steam. According to the analysis ( proximate) of the Khalaspir coal , the average heating value of coal zones i, ii, iii, iv, v, vi, vii and viii is about 11753, 11505, 10782, 11757, 10725, 10436, 11580, 11575 and 11264 BTU/ Ib respectively. These heating values are also suite to the UCG process at the Khalaspir coal deposit. In the Khalaspir coal deposit the coal are found in the upper part of the Gondwana formation and is about 284.95 m in GDH- 45, 318.60m in GDH- 46 and 257.16 m in GDH- 47 below the surface. There are eight coal zones referred to and from top to bottom as zone 1 to zone -8 (table-2, 3, 4) According to the drill hole data and proximate analysis dada and based on the parameters which is given by Andrew Beatho of CSIRO Exploration and Mining, Peter Sallans of Liberty Resources Limited, Kendra L. Zamzow of Center of Science in Public Participation, we may predict as

a) Seam– i, ii and iv may be highly potential for UCG process.
b) Seam- v and vi may be moderately potential for UCG process.
c) Seam- vii may be poorly potential for UCG process.
d) Seam- iii and viii may not be potential for UCG process

## 5. Conclusion:

Underground Coal Gasification is one of the clean coal technology brings a great promise for commercial and economically competitive power and fuel production. Generally the product gas contains methane (5-14%), Hydrogen (25-40%), Carbon dioxide (25-40%), Carbon monoxide (5-20%), Hydrogen Sulfide (2-8%) and Water (33%) (Zamzow, L.K.2010). The product gases can be used in various fields like as a fuel in fire combined cycle gas turbine power plant, synthesis of liquid fuel, manufacturing of chemicals such as ammonia and fertilizers, production of hydrogen gas, production of $CO_2$ and CO by carbon capture technology and storage to use in enhanced petroleum recovery technology. This process avoids the need for coal mining, transportation, preparation, gasified equipment and disposal of ash content having a high recovery rate above 95%. It is known to all that the most of the industry are located eastern part of the country due to availability of gas or fuel. For this reason the north western part of the country remain in off light. However Coal will play a major role in the current energy crisis situation in Bangladesh. The research works and development of UCG technology in Khalaspir coal field, therefore deserves due attention right from now Bangladesh and government should take the following steps

- Provide research fund and facilities for the UCG as alternative of underground and surface mine.
- To overcome the energy crisis especially in north-western part of the country development of coal field is very necessary.

## 6. References:

[1] Islam, M.N, Uddin, M.N, Resan,S.A, Islam,M.S, Ali,M.W.,1992,Geology Of The Khalaspir Coal basin.
[2] Imam.M.B., 2013, Energy Resources Of Bangladesh, Second Edition.
[3] IMC Group Consulting Limited, 2009. Review of “Techno-Economic Feasibility Study” Khalaspir Coal Mine.
[4] Friedmann, S.J and et al, 2009, Prospects for Underground Coal Gasification in Carbon –Constrained World.
[5] Islam, M.R 2008, Geology and coal bed methane resource potential of GondwanaBarapukuria, Dinajpur, Bangladesh.
[6] Imam, M.B., Rahman, M., Akhter, S.H., 2002. Coal bed methane prospects of Jamalgonj Coalfield, Bangladesh. The Arabian Journal for Science and Engineering 27, 17–27.
[7] Mia, I and Alam, M. N, 1984. Report on the Electrical resistivity survey to locate shallow basement feature around Phulbari area, Dinajpur District. Geol. Surv. Rept ( unpubl)
[8] Survey of Bangladesh topographic sheet No. 78 G/3.
[9] Zamzow, L.K.2010, Underground Coal Gasification, History, Environment Issues, and the Proposed Project At Beluga, Alaska.
[10] Reimann, K-U and et al, 1993. Geology Of Bangladesh.
[11]UCG Engineering, Ltd., 2006, Underground Coal Gasification: Basic Concepts.andhttp://www.coal-ucg.com/concept2.html