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# UNDERGROUND COAL GASIFICATION: A CLEAN COAL TECHNOLOGY AND ITS PROSPECT IN BANGLADESH

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***Abstract***- *Five major Gondwana coalfields have been developed by the Geological survey of Bangladesh with the total in situ reserve 2247 million tons (this energy is equivalent to 67Tcft of gas) in our country. However it is not technically feasible or economically viable to mine all coal resources and therefore there is a need for technologies for utilization of coal efficiently and cleanly. Underground coal gasification (UCG) is a potential clean coal technology which converts coal into combustible gas in situ. Typically, the syngas obtained from UCG is used for power generation via the steam turbine route. UCG offers many advantages over the conventional mining and gasification process. It is well proven technology in many countries and experience of UCG in Bangladesh is minimal. Potential for UCG in Bangladesh is studied by comparing the properties Bangladeshi coal with the properties of coal that are utilized in various UCG trails. This study will help to motivate both applied and theoretical research work on UCG sites in Bangladesh and after detailed analysis it will provide basic data to interested industries.*

**Keywords:** UCG, clean coal technology, syngas.

## 1. INTRODUCTION

Bangladesh is passing very vulnerable situation in the energy sector. The possible sources and raw material which can be converted into energy are also limited. One of the possible mine is coal which could be used for energy production. The Geological Survey of Bangladesh (GSB) discovered five coal fields in Bangladesh. The estimated coal reserve is more or less 3300 million tons where in situ reserve is 2247 million tons in our country [1]. There is a need for technologies for utilization of coal efficiently and cleanly. Coal usage has been affected by the pollution caused by its transport, storage, and combustion [2]. To deal with these problems, "clean coal technologies" have been adopted worldwide such as integrated gasification and combined cycle (IGCC); the pressurized bed combustor (PBC) combined cycle etc [3].

Underground coal gasification is an auspicious technology as it is a combination of mining, exploitation and gasification. The main motivation for moving toward UCG as the future coal utilizing technique is the environmental and other advantages over the conventional mining process. Increase worker safety, no surface disposal of ash and coal tailings, low dust and noise pollution, low water consumption, larger coal resource exploitation and low methane emission to atmosphere are some of these benefits [4]. UCG is particularly advantages for deep coal deposits and steeply dipping coal seam. But UCG involves some environmental impact such as land subsidence and ground water reserve pollution, which serves as a disadvantage. Thus before the UCG site is selected there is need for a through environmental impact assessment and complete risk analysis. These sites will be selected based on various consideration including coal quality, area, and environmental aspect. UCG is relatively well developed in many countries like the USA, Russia, France, Spain and China [5]. They have performed a number of field trials and are ready to commercialize UCG technology.

The objective of this paper is to analyze the feasibility of UCG for application to various coal mines of Bangladesh based on quantitative information available in open literature.

## 2. COAL OF BANGLADESH

### 2.1. Coal reserves of Bangladesh

High-quality bituminous type Gondwana coal of Permo-Carboniferous age has been discovered at five places Barapukuria, Dhigipara and Phulbari in Dinajpur district, Khalaspir in Rangpur district and Jamalganj in Bogra district. All these coal fields are located in the north-northwestern part of the country [5]. The total reserve of coal in four coal fields (Barapukuria, Phulbari, Khalaspir and Dhigipara) is estimated at about 2247 million tones shown in Table: 1. The Jamalganj field has an estimated coal deposit of about 1050 million tons [6] Which are lies in the depth ranges 640 – 1158 meters

Table 1: Coal fields and reserves/resources in Bangladesh (Sources: Petrobangla, GSB, AEC) [6, 7].

| Coal field | Depth of coal seams (m) | No. of coal seam | Coal seam avg thickness (m) | Type of coal seams | Reserve in million tons |
|---|---|---|---|---|---|
| Barapukuria | 116-506 | 6 | 51 | Bituminous | 390 |
| Phulbari | 150-240 | 2 | 38.41 | Bituminous | 572 |
| Khalaspir | 257-480 | 8 | 42.30 | Bituminous | 685 |
| Dighipara | 328-407 | 7 | 42 | Bituminous | 600 |
| Jamalganj | 640-1158 | 7 | 64 | Bituminous | 1053 |

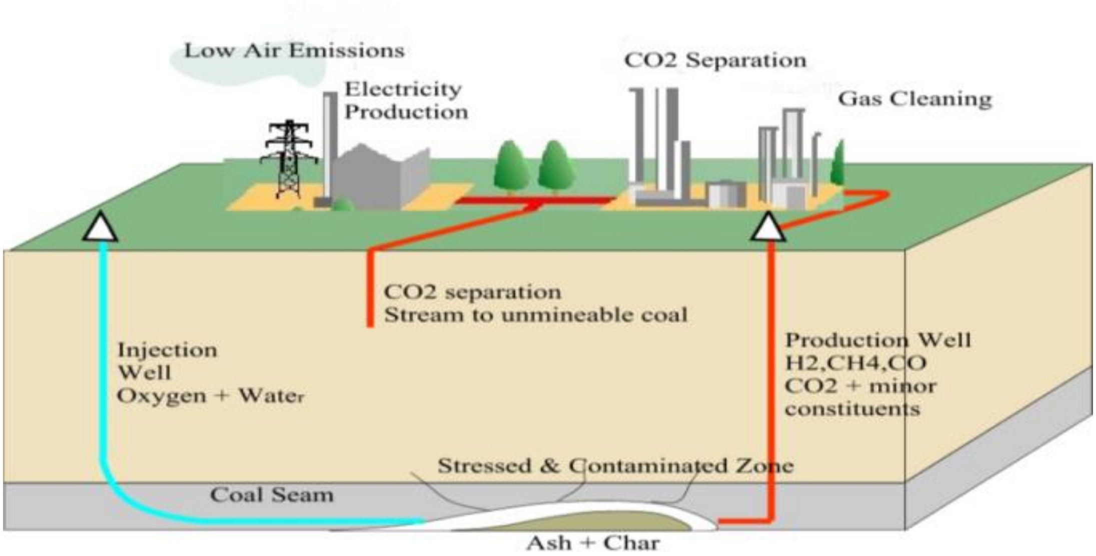


Fig.1: The schematic of the UCG process (Source: Burtonet al., 2007)

**2.2 Geological origin of coal fields in Bangladesh**

Coal deposits of Bangladesh is formed by the geological process of burial of forest in Permian age about 270 million years ago and occurs within fault bounded Gondwana basins [7]. The coal basins lie on Precambrian basement in the stable platform in North-West (NW) part of Bengal Basin. A very large forest and swamphy environment existed during that time in the NW Bangladesh and adjacent Indian state of West Bengal and Bihar. The Gondwana super continent consisted of India plus NW Bangladesh, Australia, Africa, South Africa and Antarctica, all jointed together in the geological past. The coal deposits were affected by faulting and the coal preserved in the fault bounded basins known the half graben [7].

**2.3 Properties of these coal fields**

The coal found in NW Bangladesh is high volatile bituminous coal with low to insignificant sulfur content. The quality of the coal is very good. The coal seams occur at depth ranges from 118 m to 500 m in Rangpur saddle unit and in Bogra shelf are found at depth from 600 m to more than 1000 m below the surface [7]. Thick to very thick multiple coal layers (seams) are found in the coal fields of Bangladesh. For example, Barapukuria coal field has six seams, Khalaspir has eight seams, and Jamalganj has also seven seams. The ash content of coal ranges from 11% to 25%, sulfur content 53% to 80% [8].

**3. UNDERGROUND COAL GASIFICATION**

UCG typically consists of two adjacent bore holes drilled into a coal seam and involves the injection of steam and air or oxygen into an underground steam of coal which is ignited, and reacts in the presence of injected gases to form a combustible gas that can be used either as a fuel or as a chemical feedstock. The input gases are introduced through an injection well and the product gas removed at the production well. The main constituents of the product gas are $H_2$, $CO_2$, CO, $CH_4$ and steam. The property of these gases varies with the type of the coal and efficiency of the gasification process. Figure 1 shows the schematic of the UCG process [9]. The reaction that occurs between the solid coal and injected gases underground includes the following:

$$C + O_2 \rightarrow CO_2 \text{ (+heat)} \quad (1)$$

$$C + CO_2 \text{ (+heat)} \rightarrow 2CO \quad (2)$$

$$C + H_2O \text{ (+heat)} \rightarrow H_2 + CO \quad (3)$$

$$C + 2H_2 \rightarrow CH_4 \text{ (+ heat)} \quad (4)$$

The synthesis gas produced from coal gasification can be used in a combined cycle system for the efficient and clean generation of electric power. It is also suitable for the manufacture of hydrogen and chemicals such as ammonia, methanol, acetic acid and so on [9]. It can be used in multipurpose plants as well for the simultaneous production of electric power, chemicals, fertilizers and fuels. The gas produced can also be used to make synthetic fuels by the gas to liquids (GTL) process. The production of the product gas is due to the occurrence of various reactions between the gases and solid coal [9].

### 3.1 Determination criteria of UCG technology

Before starting UCG, various aspects of the selected site should be considered. Some of them are:
1. Exploration of the UCG site.
2. Choice of a suitable drilling technique.
3. The gasification process.
4. The use of the UCG product gas.
5. Environment and safety.
6. Economics.

#### 3.1.1. Exploration of the UCG site

The potential of the UCG site can be determined by analyzing the geological structure of the coal seam. The following selection criteria are used [10]:
(i) Coal seam thickness > 2m (ii) Depth of the coal seam > 200m. (iii) Dip between 0-70. (iv) Coal rank: low bituminous (v) the availability of good density and bore hole data. (vi) Standoff > 500m from abandoned mine working area and (vii) greater than 100m vertical separation from major aquifers.

#### 3.1.2. Choice of a suitable drilling technique

To connect the injection well and production well a suitable drilling technique is necessary. The cavity between these two wells is considered as the gasification reactor. Three methods that have been developed for this purpose are gas follows [11]:

1. Air pressurization between two vertical holes in the coal seam: This technique is used in the trail of chinchilla (Australia) and the Former Soviet Union (FSU) sites. It was successful at chinchilla for the large project and an international company offered it as a commercial process.
2. Man-built galleries in the coal: This is used in China to utilize remaining coal after mining.
3. Directional drilling in the coal seam with controlled injection: This method is used in the US and European field trials. It is more costly but has greater advantages using the Control Retractable Injection procedure.

#### 3.1.3. Gasifying process

The product gas obtained in the UCG process depends on the temperature, pressure and gasifying agent. Air steam is used for the low heating value product gas whereas for medium to high heating value gas oxygen-steam is used. Oxygen has greater advantages to increase the stability of gasifying process. The cavity made using any drilling technique serves as a reactor and many reactions such as pyrolysis, combustion, gasification and oxidation take place [11].

#### 3.1.4. The use of the UCG product gas

The gas obtained by UCG is used mainly for the electric power generation and syngas is used for manufacturing of the crude oil equivalent (diesel, naphtha and wax), other liquid fuels (DME, methanol) and ammonia methane. The UCG operation in Chinchilla is the longest in duration and used for maximum power generation.

#### 3.1.5. Environment and safety

The various environmental issues associated with UCG process are [11]:
1. Surface subsidence: To reduce surface subsidence the multiwell technology can be used.
2. Groundwater contamination: Detailed analysis is needed to choose UCG and it should be away from the water aquifer. Regular checkup of the water near the UCG site should be done after UCG start up
3. CO2 emission: In the UCG process CO2 emission is the major concern as it produced in significant amount during the gasifying. CO2 must be captured before venting to the atmosphere and stored for the various applications.

#### 3.1.6. Economics

The size of the coal resource is a major commercial factor for the development of the underground coal gasification process. The market price of the product gas is also an important factor for developing UCG. The power or chemical plant should be nearby to utilize the product gas to minimize to the transportation cost.

### 3.2 UCG FIELD TRAILS

There are many countries have practiced UCG to vast reserves of unminable coal. A fully operational UCG trial at a depth of 1200m was undertaken from 1981 to 1986 in France. A commercial trial was started in 1999 at a site near Chinchilla, Brisbane, at a depth of 130m and a 40MW power plant was constructed. Russians began their UCG trials in 1933 and have considerable experience in shallow (<200 m) UCG technology. They have operated UCG plants having a capacity up to 1000MW [11].

Up to 1979, three commercial scale plants were operated at Shatsky, Angren and Yushno-Abinsk.

The USA has conducted more than 30 experiments on underground coal gasification between 1972 and 1989 for depths less than 300m [10, 12].

The various trials and their details are presented in Table 2. The properties of coals utilized for the UCG field trials are shown in Table 3. The product gas composition from the UCG trials is shown in Table 4.

## 4. FEASIBILITY STUDY OF UCG IN BANGLADESH

In this section, Bangladeshi coal seam properties like depth and thickness are discussed. As there is little previous study of UCG in Bangladesh, So Bangladeshi coals are compared with the other coals, which are used for the worldwide UCG trials.

### 4.1. Coal depth, quantity and thickness in Bangladesh

The coal at greater depth (> 300m) can be used by UCG technology economically. Bangladeshi coal properties are discussed in table 1. The coal seams in Bangladesh are suitably deep and have a thickness > 2m with the vast reserved. If the same criteria of UCG site selection are applied in Bangladeshi coal fields as that in the UK, then depth and thickness of these coal reserves are favorable for UCG.

Table 2: UCG coal type and thickness [11, 12]

| Location | Coal type | Thickness (m) | Depth (m) | Year | Comment |
|---|---|---|---|---|---|
| Yuzhno -Abinskaya | Bituminous | 2.2-9 | 50-300 | 1999-current | Used for heating |
| Angrenslkaya | lignite | 2-22 | 120-250 | 1957-current | Used for power generation |
| Chinchilla (Australia) | Bituminous | 8-10 | 130 | 1999-2004 | Used for power generation |
| USA (Hanna -2) | Sub-bituminous | 6.8 | 90-120 | 1973-1974 | The best UCG test |
| France | Anthracite | - | 1200 | 1981-1986 | unsuccessful |

Table 3: The product composition of UCG gas [10, 12]

| Location | $CO_2$ | CO | $H_2$ | $CH_4$ | $H_2S$ | $O_2$ | $N_2$ |
|---|---|---|---|---|---|---|---|
| Lisichanskaya | 26.7-28 | 6-8 | 13-15 | 2-2.4 | 1.6-1.9 | 0.2 | 46-49 |
| Yuzhno-Abinskaya | 14.3 | 10.6 | 14 | 2.3 | 0.03 | 0.2 | 58.3 |
| angrensikaya | 19.5 | 5.4 | 17 | 2 | 0.4 | 0.6 | 54.8 |
| Podmoskovnaya | 17.6 | 6 | 15.2 | 1.8 | 1.2 | 0.5 | 57.8 |
| Shatskaya | 16.9 | 6.1 | 15.1 | 1.5 | 1.2 | - | 58.5 |
| Sinelnikovsky | 20.5 | 2.1 | 11.6 | 1.3 | 0.3 | 0.5 | 63.6 |
| Hanna-2 | 12.4 | 14.7 | 17.3 | 3.3 | 0.1 | 0.5 | 51.6 |

Table 4: The properties of the UCG trial coals [11, 12]

| Location | M (%) | Ash (%) | VM (%) | CV (MJ/kg) |
|---|---|---|---|---|
| YuzhnoAbinskaya | 2.5-8 | 2.3-5.2 | 27-32 | 20-23 |
| Angrenslkaya | 35 | 12-20 | 33 | 28-30 |
| Chinchilla | 6.8 | 19.3 | 40 | 33.9 |
| USA (Hanna 2) | - | 26.26 | 36.07 | 16.20 |
| Shatkaya | 30 | 26 | 38.10 | 11.10 |

Table 5: The properties of the coal fields of Bangladesh [6, 7]

| Coal fields | Calorific value (MJ/kg) | Sulfur content (%) | Fixed carbon (%) | Volatile matter (%) | Moisture content (%) | Ash content (%) |
|---|---|---|---|---|---|---|
| Barapukuria | 24.95 | 0.53 | 48.40 | 29.20 | 10.00 | 12.40 |
| Dhigipara | 27.38 | 0.67 | 54.66 | 29.24 | 2.42 | 13.90 |
| Khalaspir | 25.46 | 0.77 | 54.10 | 22.86 | 1.28 | 21.80 |
| Jamalganj | 26.84 | 0.55 | 36.72 | 36.92 | 3.58 | 24.25 |

### 4.2. Comparisons of Bangladeshi coal seam properties with field trial coals

Table 2 show that the Yuzhno-Abinskaya, Angrensikaya, podmoskovnaya, and Chinchilla can be considered as a successful field trails. These fields have the following parameters which are important for UCG: depth 50-1200m, thickness 2-22 m, ash 2-34%, moisture 7-35%, volatile matter 27-44%, and fixed carbon 12-38%. The coal properties of Bangladesh are appeared in table 5. The depth and thickness of these sites are compared with the successful UCG trail sites Chinchilla in Fig 2. The selected sites have comparable depth and thickness as that of Chinchilla. The comparison of coal properties is shown in Fig 3. It shows that Bangladeshi coals have low ash and moisture content whereas the volatile matter and fixed carbon is high. In similar the Jamaganj coal field has significant properties what comparable with Chinchilla. However these sites may be looked upon as potential sites for the application of UCG technology implementation.

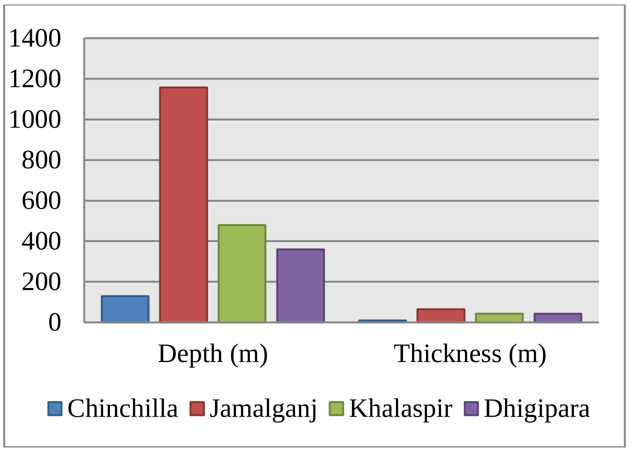


Fig.2: Comparison of depth and thickness of coal from selected sites of Bangladesh with Chinchilla.

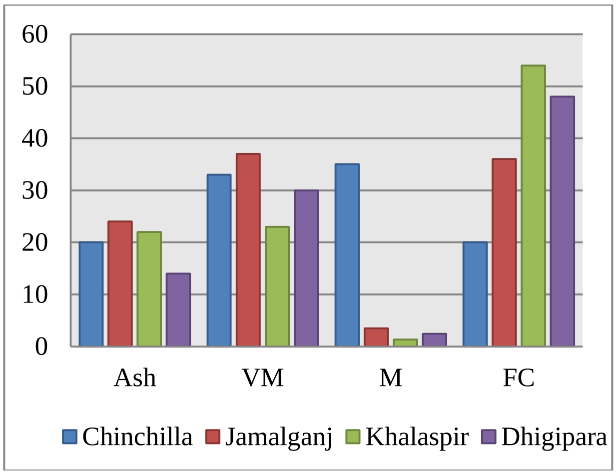


Fig.3: Comparison of coal properties of Bangladesh with Angrensikaya.

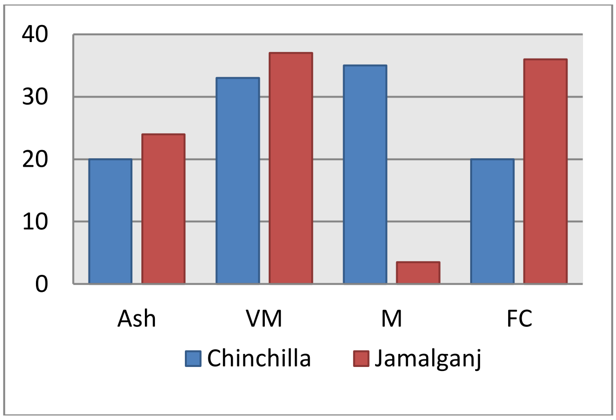


Fig.4: Comparison of properties between Jamalganj and Chinchilla.

## 5. CONCLUSIONS

Site selection of UCG is the most important issue for determining the feasibility of the application in various fields. From Table 2 the various successful field trials are shown with the coal type, depth, reserves, thickness and the other important characteristics. The successful field as a Chinchilla is found that the minimum criteria of the application of UCG in Bangladesh coal fields are also feasible.

The criteria for selecting UCG sited in Bangladesh have been formulated in this paper. Based on the available information of the characteristics of coalfields in Bangladesh the total coal reserve are 2247 million tons and only Jamalganj coal field has1053 million tons of coal occurring in the depth level between 640 to 1158m below surface. The coal type of Bangladesh is highly bituminous with low ash and moisture content whereas the volatile matter and fixed carbon is high comparing with the successful UCG field trials. The properties of the Jamalganj coal field is also the average value of ash content 24.25%, Moisture content 3.58%; volatile matter 36.92%; sulfur content 0.55% and the calorific value is 26.84 MJ/kg.

Since discussion on UCG are at an initial stage, so planning and public perception issues are to be discussed at later of the commissioning of the project. Before starting an UCG project complete environment and risk management study should be undertaken.

However, after comparison of the coal of Bangladesh with the coal used in worldwide UCG trails, it seems that Jamalganj coal field offers good prospect of the UCG development project.

## 6. ACKOWLEDGEMENT

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## 8. NOMENCLATURE

| Symbol | Meaning | Unit |
|---|---|---|
| *D* | Depth | (m) |
| *T* | Thickness | (m) |
| *CV* | Calorific Value | MJ/Kg |
| *M* | Moisture content | % |
| *VM* | Volatile Matter | % |
| *FC* | Fixed Carbon | % |