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Review Article

A Brief Overview of CBM Development in India

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Usage of coal as a source of clean energy is a priority area for Govt. of India to meet the overall objective of a low carbon path; hence Clean Coal Technology (CCT) is being pursued under a National Mission Program. The CCT is a broader term that includes all the technologies which can help reduce emissions during various stages of the coal cycle.Exploration and production of Coal Bed Methane (CBM) and its commercial utilization also comes under a larger umbrella of CCT. Studies show that the CBM reserves in Gondwana basin of India hold significant prospects to ensure sustainable energy supply in the future, and provide a potential option for CO_2 sequestration. According to the DGH, prognosticated CBM resources are about 92 TCF in 12 states of India and the commercial production of CBM in India has already commenced w.e.f. July 2007 in Raniganj (South) block in West Bengal. In this paper, we present a brief overview of development of Coal Bed Methane (CBM) and Coal Mine Methane (CMM) in India.

Keywords: CoalBed Methane; Clean Coal Technology; CBM Resources in India; Extraction of Coal Bed Methane; ECBM

Coal Bed Methane

Methane, which is identified as one of the prominent greenhouse gases, is present in the coalmines due to coal formation process. The Coal Bed Methane (CBM) is mainly composed of Methane (CH_4) with minor amounts of Nitrogen, Carbon Dioxide, and heavier hydrocarbons like Ethane. The Methane present in coalmines is a severe safety hazard during mining operations, and in earlier years of coal mining activity, this gas was vented into the atmosphere. However, if effectively recovered, CBM can be considered as a precious clean source of unconventional hydrocarbon energy resource. In past few decades, our energy requirements are rising exponentially, and due to this the CBM has become a valuable energy resource. Around the world, many coal producing countries have CBM reserves but the recognized active CBM player countries are USA, Canada, Australia, China, and India. Many countries are putting their best efforts forward to develop a technology for CBM extraction from deeper coal seams, as the depth plays a major role in the gas content of the seam. In general, the deeper the coal seam, the higher the quality of coal and higher the coal's gas content; this makes the extraction process more challenging. Nevertheless, the extraction of CBM from coalmines has three fold advantages:

- Reduction in emission of greenhouse gas from coal mines
- Safer coal mining by degassing the coal seams
- Increased domestic gas production

Indian Scenario

According to the 14th report submitted by Standing Committee on Petroleum and Natural Gas (SCPNG), the contribution of CBM to domestic natural gas production was only 1.6% in May 2016. According to the Central Mine Planning and Design Institute (CMPDI), the Methane capture and its utilization from coalmines in the past has not been undertaken in India due to the following reasons:

- Lack of latest technology

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- Lack of expertise and experience and
- Pervasive perception that commercial viability of exploitation and utilization of Methane are doubtful

India has made significant development in the technology required for exploration and production (E&P) of conventional hydrocarbons, but the challenges associated with extraction of CBM are different. The coal seams serve both as a source and as a reservoir rock for methane, and while the gas in conventional hydrocarbon reservoirs is found in a free-state in a compressed condition. A large volume of gas in coal beds lies in the adsorbed state. This is a severe challenge for existing gas extraction technology. Further, it was recognized in the past that standard seismic experiments, as used in the oil industry, were far from optimal for coal/CBM exploration. Due to these reasons, many blocks prospective for CBM remained unexplored.

Background of CBM Exploration in India

India has the fourth largest proven coal reserves in the world, and hence, it has significant prospects for exploiting CBM. A map representing different coal fields of India is shown in Fig. 1. The studies carried out by the Geological Survey of India (GSI) indicated that the Gondwana coal fields that host the high rank coal in India have enormous potential for thermogenic methane generation. Accordingly, GSI initiated a baseline data generation program for CBM in collaboration with the Oil and Natural Gas Corporation

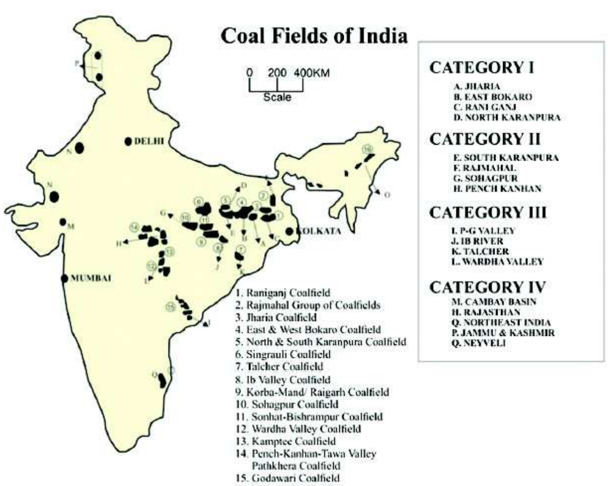

Fig. 1: Different category coal fields in India (Peters *et al.*, 2000)

(ONGC) and CMRI (now called asCentral Institute of Mining and Fuel Research (CIMFR))in selected parts of Raniganj (West Bengal), East-Bokaro (Jharkhand) and Sohagpur (Madhya Pradesh) coalfields. However, the development program gained momentum with the announcement of Coal Bed Methane-policy in 1997, which laid the foundation for the commercial exploitation of CBM. According to the GSI data,Gondwana basin in India covers an area of 52246 sq. km. However, the prognosticated potential coal bearing area is only 19262 sq. km. Consequent to the announcement of CBM policy, 33 CBM/LBM (Lignite Bed Methane) blocks covering an area of 16613 sq. km were allocated for commercial development. In these blocks, the areas where coal mining was not envisaged for the next 15-20 years were considered for CBM development, because simultaneous extraction of CBM and coal was not feasible.

CBM Resources in India

India had vast CBM reserves, but no assessment on total prognosticated CBM resources is available. The Ministry of Petroleum and Natural Gas (MoPNG) in consultation with the Ministry of Coal (MoC) and CMPDI has identified 26000 sq km area in the Gondwana basin for CBM operation. The total estimated CBM resources in this designated area are about 2600 Billion Cubic Meters (BCM) (91.8 Trillion Cubic Feet (TCF)) (14th report submitted by SCPNG, 2016). The state-wise distribution of CBM resources along with the established reserves is given in Table 1. From this table, we observe that India has approximately 91.8 TCF prognosticated CBM resources, mainly in Jharkhand, Rajasthan, Gujarat, Odisha, Chhattisgarh, M.P. and West Bengal. However, the established CBM reserve is only 9.9 TCF and that too is limited to only three states (West Bengal, M.P. and Jharkhand) till 2016. This is due to the fact that the Gondwana sediments of eastern India (Damodar, Koel valley and Son valley) host the majority of the best prospective areas for CBM development and hence all the allotted CBM blocks (DGH, 2019). Table 2 shows a brief status of these 33 CBM/LBM blocks allotted for the development. It is clear from this table that most of these blocks are still in the development stage, and only a few are in an early stage of production.

Table 1: State-wise distribution of CBM resources in India (Reproduced from 14th Report submitted by SCPNG, 2016)

State-wise distribution of CBM resources and reserves established

S.No.	State	Prognosticated CBM resource (in BCM)	Prognosticated CBM resource (in TCF)	Established CBM reserves (in TCF)
1	Jharkhand	722.08	25.5	1.916
2	Rajasthan	359.62	12.7	0
3	Gujarat	351.13	12.4	0
4	Odisha	243.52	8.6	0
5	Chhattisgarh	240.69	8.5	0
6	Madhya Pradesh	218.04	7.7	3.65
7	West Bengal	218.04	7.7	4.33
8	Tamil Nadu	104.77	3.7	0
9,10	Telangana & Andhra Pradesh	99.11	3.5	0
11	Maharashtra	33.98	1.2	0
12	North East	8.5	0.3	0
Total CBM resource		2599.48	91.8	9.9

We further observe from Table 2 that a large number of blocks are relinquished, which probably happened because of an inaccurate assessment of CBM prospects. As mentioned in the 14th Report submitted by SCPNG (2016), only a few available boreholes were utilized for extrapolation of data that are required for the resource estimation in the entire CBM contract area. Detailed surface geophysical surveys were not carried out to map the deeper coal seams.Later, it was proposed to carry out comprehensive exploration activities to establish CBM potential in India, and hence CMPDI has taken initial steps for identification of potential areas within Coal India Limited (CIL) mining leasehold in Damodar Valley coalfields, which appears to hold potential CBM. Subsequently, two blocks, one in Raniganj coalfield (approximately 57 sq.km in active mining areas) and another in Jharia coalfield have been demarcated for the commercial exploitation of CMM. An action plan was drawn for the requisite development activities. The present day major CBM projects exist in Raniganj (South, East and North),

Table 2: Status of 33 CBM Blocks Awarded (Reproduced from 14th Report submitted by SCPNG, 2016)

CBM Policy formulated in:	1997
MoU signed between MoP&NG&MoC	09.09.1997
Total CBM rounds conducted	4
No. of CBM Blocks awarded	33
Coal bearing Area Identified for CBM	26,000 Sq. Km.
Area covered under 33 CBM Blocks	16,613 Sq. Km.
CBM Resources identified in the area made available (26000 sq km)	2600 BCM (91.8 TCF)
CBM Resources (In 33 Blocks)	1767 BCM (62.4 TCF)
Established CBM Reserves (Gas in Place- GIP)	280.34 BCM (9.9 TCF)
Commercial Production commenced	July 2007
Total No. of CBM Wells drilled	725
Investment made as far	US$ 1167 MM (TiII FY 2014-15)
Present Gas Production (as on May 2016)	1.3757 MMSCMD from 5 CBM blocks
No. of CBM Blocks in Development Phase	8 (Including 2 which entered Production phase)
No. of CBM Blocks in Exploration Phase	4
No. of CBM Blocks relinquished	4
No. of CBM Blocks awaiting PEL	2
No. of CBM Blocks under relinquishment	14
No. of CBM Blocks whose Contract is terminated due to non-compliance of Contract Conditions	1 (presently under Arbitration)
Annual CBM production in FY 2015-16:	392.865 MMSCM

Jharia (Parbatpur) and Bokaro (East and West) coalfields of Damodar valley. The Son valley CBM projects include Sonhat North and Sohagpur (East and West) (DGH 2019). Apart from the excellent quality prospect, Damodar valley is the main focus for CBM projects because a majority of coal resources in these coalfields are confined within 600m and about 15-20% of these resources have already been exhausted due to mining, which makes CBM exploitation possible. Although it is premature to estimate a recovery factor of CBM blocks in India, a tentative recovery factor is expected to be varying between 12% for Bokaro to 70% for Raniganj-South with an average recovery factor of 32% (14th Report submitted by SCPNG (2016). Hence, enhancing CBM production is one of the priority areas as identified by the Govt. of India to increase the domestic gas production.

High Resolution Seismic Surveys (HRSS) for CBM Exploration

Though seismic prospecting is a standard practice in the oil industry to detect structures favorable for hydrocarbon accumulation; this method offered very little for the coal exploration. The seismic data provide spatially continuous information to detect the subsurface target zones, and its resolution is proportional to the frequency bandwidth (Goossens and Buchanan, 1984). Since the burial depth of most oil and gas reservoirs is more than 1 km, the frequencies used for the exploration of hydrocarbons are not sufficient for the exploration of thin coal layers lying at shallow depth. Thus, to delineate the coal seams, high resolution seismic prospecting was required.

Before 1970s, the high-resolution seismic prospecting was mainly confined to engineering geological applications and for very shallow investigations, but the CBM reservoirs are comparatively deeper targets for the conventional HRSS. Thus, for CBM exploration, these surveys can be designed to acquire both high and low frequencies data. Further, a high resolution processing methodology needs to be applied to preserve the information in broad frequency bandwidth, while eliminating the high frequency noise. This requirement makes HRS data acquisition and processing more challenging than the conventional seismic prospecting and it needs more research. To accomplish this, CSIR-National Geophysical Research Institute (NGRI) in collaboration with CMPDI has carried out 3D-high resolution seismic surveys for CBM exploration in two blocks of Gondwana basin in eastern India. The data is being processed, and after detailed analysis, this data will provide valuable information on the available CBM reserves in these two blocks.

Extraction of Coal Bed Methane

Extraction of CBM from coal seams is a complex process. The steps involved in the CBM extraction process are:

- Desorption of CBM from the coal surface inside the micro-pores
- Diffusion of gas through the coal matrix and
- Flow through cleat system/natural fracture network in the coal to the wellbore (Gerami *et al*., 2007).

Depending on whether methane is extracted during or after coal mining or from a virgin mine, a suitable well system is needed. Multiple wells are required to develop a CBM reservoir. In conventional CBM extraction, initially, groundwater in the reservoir is pumped out to deplete the reservoir pressure to the methane desorption pressure. Due to this mechanism, methane production lags water production. Once the desorption pressure is attained, methane production increases. After a certain period, CBM production declines due to depletion of methane in the drainage area of the well and the reduced permeability of the coal seam. The three stages identified in the conventional CBM production are shown in Fig. 2. To overcome the problems associated with the conventional methane recovery, Enhanced Coal Bed Methane (ECBM) recovery methods are developed. The ECBM is defined as the enhancement of methane desorption rates using a technique that eventually increases methane production from coal beds. There are various ways to implement ECBM method (Puri and Yee, 1990; Wilson *et al.*, 1995; Chaback 1996; Gunter *et al.*, 1997; Parakh, 2007; White *et al.*, 2005; Mazzotti *et al.*, 2009; Busch and Gensterblum, 2011; Ranathunga *et al.*, 2017; Sampath *et al.*, 2017) and of various ECBM techniques, CO_2 injection based methods have become popular due to their added

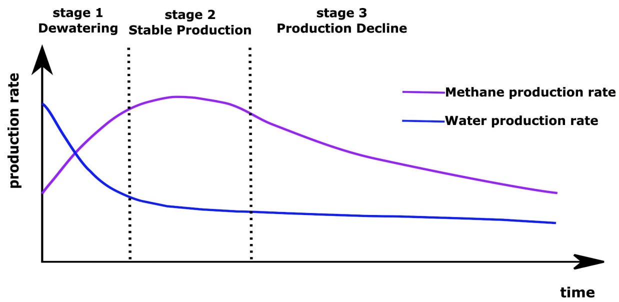

Fig. 2: Stages in conventional production of CBM (Rice and Nuccio 2000; Sampath *et al*., 2017)

contribution in reducing the greenhouse gas effect through arresting CO_2 into the coal seams. This process is quite simple, as coal prefers carbon dioxide, and it releases methane to sorb injected CO_2. Thus CO_2 based ECBM significantly increases the amount of methane available for production, but it also causes the coal to swell, reducing its permeability with time. However, an additional benefit of CO_2 injection for ECBM is that the methane can be desorbed, while maintaining higher reservoir pressures, which results into added energy to drive methane to the wellbore (SPE 201-2019).

In a study carried out by the IEA Greenhouse Gas R&D Programme (IEAGHG), it was concluded that the estimated recovery potential for methane from the world's coal seams is 79 trillion cubic meters (TCM). Out of which only 29 TCM is associated with the conventional CBM recovery, and 50 TCM is associated with the CO_2- ECBM recovery as a secondary production technique (Godec *et al*., 2014).

The CO_2 can be used to enhance the production of coal seam gas broadly by two mechanisms:

- by exchanging the methane due to its high sorption capacity and
- as a fracturing fluid to effectively fracture the coal seam

The process of methane-CO_2 gas exchange based ECBM is illustrated in Fig. 3. The ECBM recovery projects have been commercially developed all over the world including the countries like the USA, China, and Australia (Busch and Gensterblum, 2011). However, it should be noted that for CO_2 to flood the CBM reservoir and sweep out the methane, the coal seams should have a moderate to high permeability (at least 1 mD) that may limit the commercial application of ECBM techniques in many coal fields. The technical feasibility of CO_2 driven ECBM has been studied through numerical modeling and simulation studies in Jharia and Raniganj coalfields (Vishal *et al*., 2013; Vishal *et al*., 2018). The simulation studies show that 218 Mm^3 of CO_2 can be sequestered in place of 74 Mm^3 of methane produced from chosen dimensions of Raniganj coalfields and approximately 220 Mm^3 of CO_2 can be sequestered in place of 62 Mm^3 methane in Jharia coal fields. These studies confirm that the Gondwana coals of India have good potential to absorb CO_2 and a significant enhancement in the production of methane can be achieved by implementing ECBM recovery method. However, the CO_2 driven ECBM techniques are still novel for the CBM extraction industry. Therefore, a detailed study of CBM reservoir properties, long-term feasibility assessment, and complete risk analysis are necessary before its implementation.

It is worth mentioning here that the CBM can be recovered from various types of mines, like operational coalmines, abandoned coalmines (AMM), and virgin (unmined) coal seams. The gas composition might change depending on the stage of the coalmine. Hence, the CBM extraction procedure may differ from mine to mine (Creedy and Tilly 2003; Wang *et al*., 2014).

CBM Production in India and the Road Ahead

The CBM ventures started systematically in India in late 1990s. The exploitation of CMM and AMM was taken under the United Nations Development Project (UNDP)/Global Environmental Facility (GEF)-Govt. of India. A pilot scale demonstration of the project at two sites viz. Moonidih and Sudamdih mines of Bharat Coking Coal Limited (BCCL) has taken place. Under this project, three CBM wells were drilled at Moonidih site of the Jharia coalfield down to a depth of 1059 m, where CBM is being produced from wells drilled for the purpose and is being utilized to generate electricity from thegas-based generator. However, at Sudamdih site,due to technical issues, underground drilling could not be completed. The Great Eastern Energy Corporation Limited (GEECL) commenced CBM production at commercial scale in July 2007 in Raniganj coalfield. Besides GEECL, ONGC, Essar Oil Limited

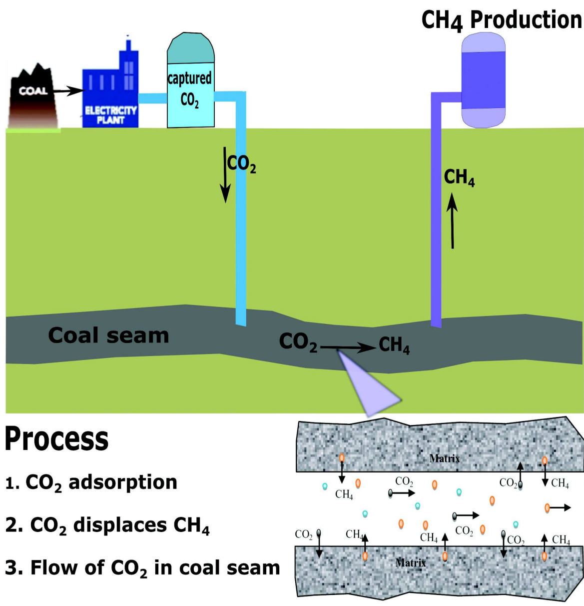

Fig. 3: Enhanced CBM production using CO_2-CH_4 gas exchange

and Reliance Industries Limited (RIL) are also producing CBM at commercial scale in Raniganj, Jharia and Sohagpur coalfields respectively. From five CBM blocks, approximately 2 Million Standard Cubic Meters per day (MMSCMD) of CBMis being produced (Singh and Hajra, 2018).

In other coalfields of India, although, the combined potential of VCBM, CMM, and AMM appears brighter, the socio-economic and environmental factors are controlling the commercial production of CBM. India has already opened up the mine free areas in different coal basins for exploration and exploitation of VCBM and required policy for development is in place. Now,the implementation of advance technology for explorationand extraction is required. CMPDI is implementing R&D projects for identification of a suitable area for CMM development, and few blocks have been identified. CSIR-NGRI has carried out HRSS survey to map the thickness of coal seams in blocks suggested by CMPDI in Jharkhand and Orissa, and based on these studies exploratory wells can be drilled, and cores can be analyzed to assess the CBM potential. The blocks that are already under development may adopt advanced technology of high tech wells to increase the rate of production. The ECBM recovery using CO_2 gas exchange method is also a promising alternative to boost commercial production of CBM.

A successful CBM development program would need a detailed understanding of the reservoir and efficient technology, suitable for Indian basins. Further, simultaneous mining of coal and CBM is being done in other countries to boost the production. It is possible to do the same in India where sufficient areal distances are maintained between the coal mining and CBM operations. These steps will not only augment our natural gas production but also help in curbing the release of greenhouse gases in the atmosphere.

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