Coal Bed Methane in India: Difficulties and Prospects

Keka Ojha, B. Karmakar, A. Mandal, and A. K. Pathak

Abstract—**To meet the rapidly increasing demand for energy and faster depletion of conventional energy resources, India with other countries is madly searching for alternate resources like coal bed methane (CBM), shale gas, gas hydrate. CBM is considered to be the most viable resource of these. The present paper discussed about the prospect of CBM as a clean energy source, difficulty involved in production of CBM, enhanced recovery techniques. In this regards, one Indian coal field is selected and gas content is determined by analyzing the collected samples.**

Index Terms—**CBM, CO2 Sequestration, Global Warming, Methane Recovery, Gas Content, Clean Energy, Singareni Coal Field.**

I. Introduction

Depletion of conventional resources, and increasing demand for clean energy, forces India to hunt for alternatives to conventional energy resources. Intense importance has been given for finding out more and more energy resources; specifically non-conventional ones like CBM, shale gas & gas hydrates, as gas is less polluting compared to oil or coal. CBM is considered to be one of the most viable alternatives to combat the situation [1]. With growing demand and rising oil and gas prices, CBM is definitely a feasible alternative supplementary energy source.

Coalbed methane is generated during coalification process which gets adsorbed on coal at higher pressure. However, it is a mining hazard. Presence of CBM in underground mine not only makes mining works difficult and risky, but also makes it costly. Even, its ventilation to atmosphere adds green house gas causing global warming. However, CBM is a remarkably clean fuel if utilized efficiently. CBM is a clean gas having heating value of approximately 8500 KCal/kg compared to 9000 KCal/kg of natural gas.

It is of pipe line quality; hence can be fed directly to national pipeline grid without much treatment. Production of methane gas from coalbed would lead to de-methanation of coal beds and avoidance of methane emissions into the atmosphere, thus turning an environmental hazard into a clean energy resource.

As the third largest coal producer in the world, India has good prospects for commercial production of coal bed methane. Methane may be a possible alternative to compressed natural gas (CNG) and its use as automotive fuel will certainly help reducing pollution levels.

India is one of the select countries which have undertaken steps through a transparent policy to harness domestic CBM resources. The Government of India has received overwhelming responses from prospective producers with several big players starting operations on exploration and development of CBM in India and set to become the fourth after US, Australia and China in terms of exploration and production of coal bed methane.

However, in order to fully develop India's CBM potential, delineation of prospective CBM blocks is necessary. There are other measures like provision of technical training, promotion of research and development, and transfer of CBM development technologies that can further the growth of the sector.

India lacks in CBM related services which delayed the scheduled production. Efficient production of CBM is becoming a real challenge to the E & P companies due to lack in detailed reservoir characterization. So far, the most investigations have been limited to measurement of adsorption isotherms under static conditions and is deficient in providing information of gas pressure-driven and concentration-driven conditions. More care should be taken on measurement of porosity and permeability also. To produce more methane from the coal enhanced technology like CO_2 sequestration may be implemented. This process can not only reduce the emission of this gas to atmosphere, will also help in extra production of methane gas [2]. Though, presently, CO2 is not an implemented much because of high cost. But the necessity to reduce greenhouse gas emissions has provided a dual role for coalbeds - as a source of natural gas and as a repository for CO_2.

In the present investigation, Singareni coal field has been selected as the study area. Samples have been collected from various locations & depths. Standard methods have been followed to characterize the collected coal samples and evaluation gas reserve.

II. Global and Indian Scenario

Global: The largest CBM resource bases lie in the former Soviet Union, Canada, China, Australia and the United States. However, much of the world's CBM recovery potential remains untapped. In 2006 it was estimated that of global resources totaling 143 trillion cubic meters, only 1 trillion cubic metres was actually recovered from reserves. This is due to a lack of incentive in some countries to fully exploit the resource base, particularly in parts of the former Soviet Union where conventional natural gas is abundant.

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The United States has demonstrated a strong drive to utilize its resource base. Exploitation in Canada has been somewhat slower than in the US, but is expected to increase with the development of new exploration and extraction technologies. The global CBM activities are shown in Fig.1.

The potential for supplementing significant proportions of natural gas supply with CBM is also growing in China, where demand for natural gas was set to outstrip domestic production by 2010 [3].

India: India is potentially rich in CBM. The major coal fields and CBM blocks in Indian are shown in Fig 2. The Directorate General of Hydrocarbons [4] of India estimates that deposits in major coal fields (in twelve states of India covering an area of 35,400 km^2) contain approximately 4.6 TCM of CBM [5]. Coal in these basins ranges from high-volatile to low-volatile bituminous with high ash content (10 to 40 percent), and its gas content is between 3-16 m^3/ton (Singh, 2002) depending on the rank of the coal, depth of burial, and geotectonic settings of the basins as estimated by the CMPDI. In the Jharia Coalfield which is considered to be the most prospective area, the gas content is estimated to be between 7.3 and 23.8 m^3 per ton of coal within the depth range of 150m to 1200 m. Analysis indicates every 100-m increase in depth is associated with a 1.3 m^3 increase of methane content [6].

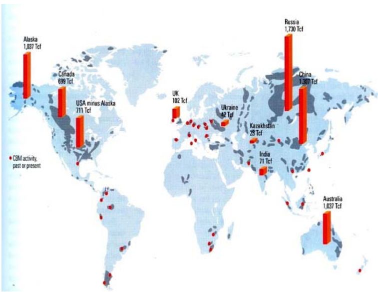

Fig 1. Global CBM activities

In India, commercial CBM production is yet to be started in full pace. Few E&P companies like ONGC Ltd., GEECL and Essar Oil have started production, but field development is yet to be completed.

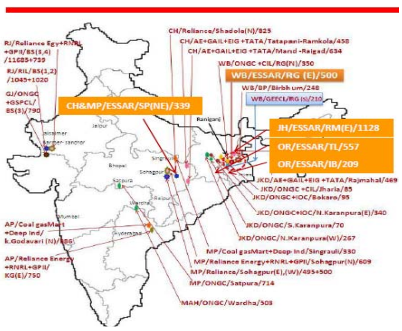

Fig. 2. CBM Blocks in India (DGH, India)

III. Materials and Method:

A. Sample collection and characterization

Coal samples were collected from Dorli- Bellampalli coal Belt of Singareni coalfield, Andhrapradesh, India. Samples are collected from various seams of the bore holes at different locations.

TABLE I. PROXIMATE ANALYSIS RESULT

BH.No.	Seam	Avg. Depth (m)	M%	Ash (%)	V.M. (%)	FC (%)
BH1	I	427	3.76	26	32.50	37.74
		431	3.01	24.94	32.75	39.30
	II	498.3	3.04	26.59	26.30	44.07
		499.7	3.38	22.82	31.62	42.18
		503	3.12	17.03	30.46	49.39
	III	541	3.53	22.65	23.30	50.70
BH2	I	369	2.95	23.00	28.96	45.10
		371	2.46	45.99	25.45	26.01
	II	435.5	3.43	25.17	33.61	37.79
		435.5	3.72	15.39	27.68	53.21
		443.5	3.15	10.52	40.26	46.07
	III	456.5	3.82	11.15	31.11	53.92

TABLE II. ELEMENTAL ANALYSIS OF THE SAMPLES

Avg. Depth (m)	C	H	N	S	O
427	54.66	4.09	1.76	0.68	9.05
431	57.49	4.12	1.63	0.66	8.15
498.3	57.47	3.79	1.69	0.59	6.83
499.7	59.42	4.22	1.73	0.55	7.88
503	66.17	4.34	1.57	0.57	7.2
541	61.89	3.77	1.59	0.43	12.17
369	44.38	3.94	1.79	0.54	8.72
371	38.44	2.91	1.48	0.49	8.23
435.5	56.36	4.12	1.67	0.51	8.74
438.5	67.68	4.31	1.71	0.55	6.64
443.5	70.24	5.07	1.66	0.63	8.73
456.5	71.01	4.58	1.69	0.60	7.15

Caprock of each seam is mainly made of coarse to very coarse grained sandstone, greyish all over. The depth under study varies from 369m to 541m.

The coal samples were first crushed, ground and sieved through 72-BSS mesh openings. Proximate analyses of the samples were performed using muffle furnace as per the standard method. The equilibrium moisture content of the samples was determined using the standard test method [ASTM D 1424 – 93]. Ash contents of samples were estimated in accordance with the ASTM D3174-04 and elemental composition of coal samples were determined using CHNS Analyzer (Elementar Vario EL III- CHNS analyzer). The results of the proximate and elemental analyses are shown in Table I and Table II respectively.

IV. Results and Discussions

From the results it was observed that the ash content varies from 10.52% to 26.59% except one sample that showed an irregularly high ash content of 45.99%. Proximate analysis of the investigated coal samples reveal that the moisture content (M %) varies from 2.46% to

3.82%, whereas volatile matter ranges from 23.30% to 40.26% and fixed carbon (FC) content varies from 26.01% to 53.21%. From elemental analysis (Table II) it is seen that the fixed carbon percentages varies from 38% to 71 %. In general it is recognized that the fixed carbon of coal increases with increase in coal depth which is directly proportional to the coal maturity and rank [8]. The similar trend is observed in the present study also as shown in Fig 3 and Table I.

A. Gradation of coal under study:

The value of vitrinite reflectance (R_o%) gives idea about the coal rank and grade. In the present study, the vitrinite reflectance (R_o%) is calculated by using the formula by Rice [9] using the data from approximate analysis. The formula is as follows:

$$R_o\,\% = -2.712 \times \log(VM) + 5.092 \qquad (4)$$

The R_o% varies from 0.45% to 0.88% (Table III).

From the proximate analysis and value of vitrinite reflectance (Ro) varies from 0.45 to 0.88%. Hence, the coal samples under study belong to sub-bituminus to bituminous rank.

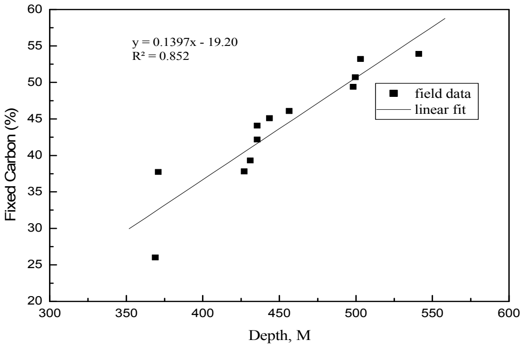

Fig. 3. Variation of fixed carbon with depth

B. Estimation of Methane Content

Most of the gas in the coal is adsorbed on the internal surface of micropores and varies directly with pressure and inversely with temperature. The relationship between the volume of adsorbed gas with pressure and temperature based on the moisture and ash content of coal samples was estimated by Kim's empirical equation [10].

Kim's correlation:

$$G_{saf} = 0.75 \times (1 - a - w_e) \times \left[k_o(0.095d)^{n_o} - 0.14 \times \left(\frac{1.8d}{100} + 11\right)\right] \ldots\ldots (1)$$

$$k_o = 0.8\frac{x_{fc}}{x_{vm}} + 5.6 \ldots\ldots (2)$$

$$n_o = 0.315 - 0.01\frac{x_{fc}}{x_{vm}} \ldots\ldots (3)$$

The estimated methane gas content is shown in Table II. From estimated gas content data, it is observed that the gas content varies from 5 m^3/ tonne to 9 m^3/ tonne as against the economic viability of 8 to 15m^3/ tonne. The values of gas content increase with increase with depth as the maturity & rank of the coal also enhanced (Table II). However, from the result it is seen that the gas content is at the lower economic limit. This may be due to less maturity of the coal and less depth.

TABLE III. ESTIMATED GAS CONTENT

BH.No.	Seam	Avg. Depth (m)	Fixed Carbon (%)	$G_{saf,}$ cc/g	R_o (max)
BH1	I	427	37.74	7.28	0.65905
		431	39.30	7.47	0.65276
	II	498.3	44.07	7.36	0.81164
		499.7	42.18	7.67	0.68109
		503	49.39	8.34	0.70994
	III	541	50.70	7.77	0.88335
BH2	I	369	45.10	7.71	0.74693
		371	26.01	5.32	0.83209
	II	435.5	37.79	7.39	0.63106
		435.5	53.21	8.48	0.77821
		443.5	46.07	8.94	0.4587
	III	456.5	53.92	9.00	0.6938

C. Relationship between Total Gas Content and Non-Coal content (ash + moisture content):

Since it is generally true that methane is not adsorbed onto non-coal material, ash and moisture values can be used to make appropriate corrections on the total measured gas contents. Gas content is seen to increase with depth, and bituminous coals are associated with the highest gas contents, followed by sub bituminous coals. Cross plot of Gas Content versus non- coal content (ash + moisture content) is shown in Fig.4.

Moisture and ash content within the coal reduces the adsorption capacity of methane. Adsorption capacity of methane decreases with increasing ash and moisture percentage within the coal. As little as 1% moisture may reduce the adsorption capacity by 25%, and 5% moisture results in a loss of adsorption capacity of 65% [11].

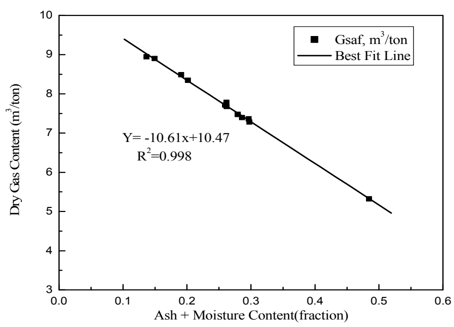

Fig. 4. Relationship between Total Gas Content and Non- Coal content (ash + moisture content)

V. Production of Gas from Coalbed.

A. Gas Transportation mechanism in reservoir:

Production of gas is controlled by a three step process (i) desorption of gas from the coal matrix, (ii) diffusion to the cleat system, and (iii)flow through fractures [12] as shown in Fig 5.. Many coal reservoirs are water saturated, and water provides the reservoir pressure that holds gas in the adsorbed state.

Flow of coalbed methane involves movement of methane molecules along a pressure gradient. The diffusion through the matrix pore structure, and steps include desorption from the micropores, finally fluid flows (Darcy) through the coal fracture (cleat) system. Coal seams have two sets of mode; breaking in tension joints or fractures that run perpendicular to one another.

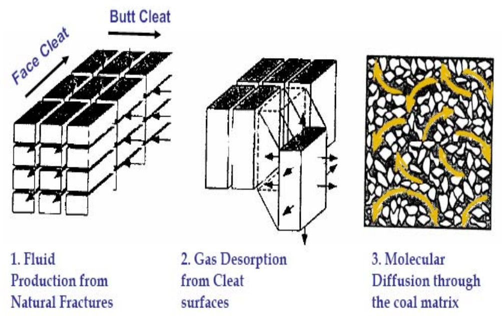

Fig. 5. Process of Gas Transport through coal beds [12]

The predominant set, face cleats, is continuous, while the butt cleat often terminates into the face cleats. Cleat systems usually become better developed with increasing rank, and they are typically consistent with local and regional stress fields.

The size, spacing, and continuity of the cleat system control the rate of fluid flow once the methane molecules have diffused through the matrix pore structure. These properties of the coal seams vary widely during production as the pressure declines. Coal, being brittle in nature, cannot resist the overburden pressure with reduction in pore pressure during dewatering; and fractures are developed. In addition, hydraulic fracturing is done to increase the permeability of coal. Because, permeability and porosity of coal is extremely low for which production rate is also low. The basic petrophysical properties of coal responsible for production of methane, e.g. porosity, permeability vary widely with change in the pore pressure during dewatering as well as gas production period. Hence, efficient production of methane from coal bed needs continuous monitoring of variation in porosity, permeability and compressibility of coal. The unique features of the coal are that coals are extremely friable; i.e., they crumble and break easily. Therefore, it is nearly impossible to recover a “whole” core. Direct measurement of intrusive properties like permeability, porosity, compressibility, relative permeability measurements are very difficult and must rely on indirect measurement.

In India, ONGC Ltd. has implemented multilaterial well technology to increase the drainage area and enhance the production in the Jharia block. But, brittle characteristic of coal restricts the production at the expected rate.

Moreover, coal is highly compressible (~as high as $2x10^{-3}$ psi^{-1}) [13]. Variation of permeability and bottom hole properties during production requires accurate well test analysis using correct model. CBM reservoirs are of dual porosity system, which demands for special models of well test analysis. So, only static adsorption-desorption study can not suffice the analysis of coal bed methane production. As these properties will continuously vary during production, efficient & economic production of methane from coal bed requires constant monitoring and analysis of the system by experienced and proficient persons.

B. Enhanced recovery techniques:

The main hurdle associated with the production of CBM is the requirement of long dewatering of coal bed before production. This difficulty may be resolved to some extent with implementing the CO_2 sequestration technology.

Due to higher adsorption affinity of CO_2 to coal surface [7], methane will be forced to desorb from the coal surface at comparatively high pressure and can reduce the dewatering time and hence the total project period. Also the problem associated with variation in coal properties related to pressure depletion may be alleviated. China, Australia, USA have been started to implement this technology for enhanced recovery of CBM gases.

VI. Conclusions

CBM technology is proceeding with good space to prove itself as a cleaner energy security to India as well as the World. However, production strategy of methane from CBM is very much different from conventional gas reservoir. The study revealed that the coal type, rank, volatile matter and fixed carbon are strongly influence the adsorption capacity of methane into the coal bed. With increasing depth maturation of coal increases and generation of methane gas also increases. Gondwana basin as the most prospective CBM field is being developed now. From the studies, it is observed that Singareni coal field under Gandowana basin contains low gas Hence, presently it is not considered for CBM exctraction. However, in future this field may be considered for methane extraction using advanced technology and in emergency condition.

Sequestration of CO_2 helps in mitigation of global warming, at the same time helps in recovery of methane gas from coal bed unveiled otherwise. However, detailed and intensive studies are required for efficient and economic production of coal bed methane. India with ~4.6 TCM of methane reserves in coal bed can enrich its per capita energy demand by successful exploitation of CBM.

Appendix

BH1= Borehole 1

BH2= Borehole 2

G_{saf} = Dry, ash-free gas storage capacity, cm^3/g

A = Ash content, weight fraction

w_c = Moisture content, weight fraction

d = Sample depth, m (feet/3.28)

x_{fc} = Fixed carbon, weight fraction

x_{vm}= Volatile matter, weight fraction

R_o= Vitrinite reflectance

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