METHANE MITIGATION IN INDIAN COAL MINING

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ABSTRACT

Association of methane with coal poses a serious explosion risk in underground coal mining. Besides, it is a potent green house gases significantly contributing to global warming. Therefore, its commercial exploitation is being widely recognised as (a) a fuel resource to bridge the energy gap (b) making coal mining safer (c) providing cleaner energy and (d) checking the building of green house gases. Indian coal seams has a vast Coal Bed Methane (CBM) potential in various coalfields but we lagged behind because of knowledge gap, inadequate funds and non-availability of suitable technology. To overcome this, Government of India has recently taken a very positive step and invited non-governmental participation by international competitive bidding on attractive terms to develop several commercially feasible CBM blocks for its commercial exploitation. The paper presents the distribution and content profile of India's vast CBM potential and status of efforts to exploit it.

1. INTRODUCTION

Energy availability and its utilisation is most important factor for development of a country. India is trying hard to meet increased energy demand from population growth and economic expansion. In power sector alone it accounts for 70% contribution while hydro (20%), oil and gas (8%) and nuclear (2%) lags far behind. We are experiencing a power shortage of 11.5% (with a peak shortage of 18%). With the demand increasing at about 10% per year, the power shortage will increasingly jeopardise future economic growth. Difficulty in increasing other sector of energy component and present energy use pattern and policy planning signify that coal will continue to provide most of our energy requirement in foreseeable future.

Coal Bed Methane (CBM), a hydrocarbon (CH_4) in gaseous form has its origin in the coalification process occurring over a period of millions of year out of accumulated plant material. Most of the CBM gas is in adsorbed state on the micro pores of the coal surface, thus coal is both the source and reservoir rock for CBM. A saturated CBM reservoir could contain up to five times the amount of gas contained in a conventional gas reservoir of comparative size, temperature and pressure. The amount of methane present in coal seams increases with rank of coal and depth of coal seams. A correlation study (Singh et al, 99) carried out at Central Mining Research Institute, Dhanbad showed an increase of 1.30 m^3/t in gas content per 100 m increase of depth.

2. METHANE HAZARD IN COAL MINING

Association of methane with coal seam is a serious safety concern since the inception of mining. Methane is an explosive gas in concentrations of 5.4 -

14.8% in air under normal underground environmental condition with explosion severity maximising at methane concentration of 9.4% (Misra, 1989). 40% of the disaster that took place in Indian coalmines between 1908-1995 are due to methane explosion accounting for 839 fatalities (Singh et al., 1999). The risk of disaster associated with methane is increasing with increased coal production particularly from deeper seams. To ensure safety, the concentration of methane gas is constantly monitored at working places and maintained below 1.25% at every place by increasing fresh air ventilation requiring additional cost. Calculation shows that 1 m^3/min of methane from a working face will require 79 m^3/min of methane free fresh air to bring the concentration of air to required level. High capacity fans are used to dilute the gas during mining and the precious energy resource is not only lost, being a green house gas, contributes to global warming. Coal Mining is reported to be contributing about 9% of total methane emission (Pande,1996). In a gassy mine, this becomes very expensive and often decides the ventilation requirement.

3. METHANE AS A GREEN HOUSE GAS

Green house gases when emitted to the troposphere, allow sun-rays to penetrate to the earth but, due to specific properties of the gases, do not permit all of the heat to reradiate back to the atmosphere resulting in an increase in temperature of the earth surface. Methane's contribution in global warming is 18% after CO_2 (66%) and followed by CFC (11%) and N_2O_5 (5%) (Prasad and Rai, 2000). Thus, Methane is a potent green house gas second only to carbon dioxide as regards to its concentration by volume in the atmosphere. Methane has a global warming potential of 21 over a 100-year period. This means that on a kilogram for kilogram basis, methane is 21 times more potent than carbon dioxide during this time period. Its present concentration in atmosphere is 1.72 ppmv (which is double of its concentration in pre-industrial period) and increasing 0.015ppmv per year. Contribution of Indian coal mining is 0.4 million tonnes per year. It has been estimated that reductions of about 10 percent in emissions would halt the annual rise in methane concentrations.

With growing human conscious and governmental effort, significant reduction trend in its growth was recorded after 1951. Since 1993, methane's global growth rate has been between 2 and 8 ppbv/year. This is much slower than the 20 ppbv/year in the late 1970s and slightly less than the 9 to 13 ppbv/year during the 1980s. Coal mining is the biggest contribution to methane load of environment. Top ten countries in methane emission by coal mining are China (13000 tons), United States (5200 tons), CIS (7100 tons), South Africa (2300 tons), India (2300 tons), Germany (1600 tons), Poland (1600 tons), United Kingdom (900 tons), Australia (800 tons) and Czech Republic & Slovakia (500 tons) (Prasad and Rai, 2000). Besides coal mining, there are many other sources contributing to methane build up in atmosphere. Table-1 (Prasad and Rai, 2000) shows the quantity of the annual global methane emission from various sources.

Table 1-Annual Global Methane Emission from Various Sources

S. No.	Source	Methane Emission (in thousand tons)
1	Live Stock	65-100
2	Rice	60-100
3	Natural Gas & Oil	32-68
4	Biomass Burning	28-51
5	Liquid Wastes	29-40
6	Coal	24-40
7	Landfills	20-28
8	Manure	8-18
9	Minor Industries	4

4. METHANE AS A CLEANER ENERGY SOURCE

On complete combustion, one kg of methane produces 55685 kJ of heat whereas, 2428 kJ and 6280 kJ of heat is produced from one kg of gunpowder and nitro-glycerine respectively (Misra, 1989). Thus, Methane is a very powerful source of energy.

Recently, Compressed Natural Gas (CNG) is being used in vehicles as the substitute of petrol and diesel. CNG contains about 80-90% methane and 10-20% other gases. It is better substitute of petrol and diesel as it produces 70% less carbon monoxide, 87% less nitrogen oxide than petrol and diesel. It also exhausts 89% less biogas in comparison to petrol and diesel (Dwivedi et al, 2001). Since, CNG causes very less pollution as compared to petrol and diesel, it is eco-friendly and the better alternative for petrol and diesel. Table-2 (Bist, 2001) shows comparative study of pollutants produced by diesel and CNG. The use of pure methane can, thus, further reduce the pollution and prove better than CNG. Thus, methane is an important environmental clean source of energy and may provide a solution to all our energy-linked miseries if its potential is properly harnessed.

Table 2-Reduction in Pollution by using CNG Operated Buses

S. No.	Pollutants	Diesel (gm/km)	CNG (gm/km)	Reduction (%)
1	Carbon monoxide	2.40	0.68	71
2	Nitrogen oxides	22.50	6.26	72
3	Ammonia	1.50	1.25	17

5. METHANE MITIGATION

Because of its potency on a ton-by-ton basis, methane reductions have a larger impact on climate change than reductions in carbon dioxide. Additionally, methane has a relatively short lifetime—about 12 years compared to 120 years for carbon dioxide. For these reasons, programs and policies that target reductions in methane emissions can help mitigate the rate of climate change at a faster rate than those that target reductions in emissions of carbon dioxide and other longer-lived greenhouse gases. Moreover, methane emissions are often associated with wasted energy. Capturing these emissions will improve operational efficiency.

Methane drainage for making gassy mines safer has been practiced for a long time. One of the most efficient drainage has been from the region of caved rocks after extraction of coal through long wall caving technology. The percentage of methane in such drainage from mines varies from 30% to 70%. Which may be useful for heating or electricity generation for the coalmine, but not good enough for a commercially viable project. To obtain higher concentrations of methane, attempts have been made to tap the methane from virgin gassy coal seams.

Among the various technologies available for mitigating methane emission from coal mining, pre-mining degasification has presently attracted worldwide attention. The technology aims at producing coal bed gas by surface boreholes in virgin coal bearing blocks and using the recovered methane as a valuable fuel resource with additional advantage of eventual reduction from the prospective mines.

The U.S. coal industry has made substantial progress in recovering and using CMM though drainage systems (US EPA. 2003). Out of 142 billion cubic feet (Bcf) of coal mine methane (CMM) liberated from underground mines in 2000, about 42 Bcf was emitted through drainage systems and remainder as ventilation air. About 86% of the methane emitted through drainge system (36 Bcf) was successfully recovered as compared to 13.8Bcf in 1990. In terms of greenhouse gas emissions, the 36 Bcf is equivalent to removing 3.2 million cars from the road.

Ventilation air still contains a considerable amount of greenhouse gas emissions to be utilized gainfully. Till recently, combustion of ventilation air methane (VAM) was not possible due to low methane concentration. Technologies now exist to oxidize and utilize the VAM. Reactors can combust the ventilation air at very high temperatures to produce thermal energy. A successful VAM pilot project has been conducted in Australia. US EPA is taking a lead role in encouraging various cost effective emission reductions strategies including VAM oxidation in US.

6. CBM RESOURCE AND POTENTIAL OF INDIAN COALFIELDS

The coal-bearing formations of India occur in two distinct geological horizons in the Lower Gondwana (Permian) belts of India and the Tertiary sediments (Eocene-Oliocene) of north-eastern India, Rajasthan, Gujarat, and Jammu and Kashmir. Methane gas is entrapped within these formations at a wide range of sub-surface depths.

In the last decade, after the realization that methane from coal bed can be gainfully utilized, many agencies and research organizations such as the Central Fuel Research Institute, the Central Mining Research Institute (CMRI), the Central Mine Planning and Design Institute (CMPDIL), the Oil and Natural Gas Corporation (ONGC), and the Mineral Exploration Corporation (MECL) have become interested in CBM and are generating useful data. Many private agencies like the Amoco and Reliance have also contributed in this regard.

Gas Authority of India Limited engaged MECL and collected all necessary data from published sources/literature from all the major and minor coalfields belonging to lower Gondwana Group, located in the five basins of peninsular India. In all 42 coalfields were studied with respect to geographical information, general geological set up, geological structure, number of coal seams, variation in the thickness of coal seams, quality characteristics and their variation, resource potential and depth wise deposition of coal reserves. ONGC carried out preliminary CBM exploration studies in Raniganj and Jharia Coalfields with the help of MECL by drilling ten to twelve boreholes of about 1000m depth. MECL drilled a borehole in the area of lignite coalfields in Tamil Nadu and in Bikaner and Barmer area in Rajasthan to indentify the potential reserves of CBM. Great Eastern Energy Corporation Limited had undertaken study of Coal Bed Methane in Raniganj coalfield in West Bengal. (Dwivedi et al, 2001).

CMRI has carried out extensive investigation on the determination of methane content of several coal beds by using Direct Method (Bertard et al., 1970) suitably modified by USBM (Diamond and Levine,1981) for exploratory boreholes. The methane content of coalbeds upto a depth of 400m has been found to be generally low ($<2m^3/t$) except in R-VIII seam, Ghusick area of Raniganj Coalfields where methane content was estimated to be 4.27 m^3/t at a depth 260 m. High concentration of methane has been observed in coalbeds at Chasnala, Amlabad, Sitanala and Parbatpur area, located in the south eastern part of Jharia coalfields in Bihar province. The highest value of 14.93 m^3/t of methane content has been measured at XIV-A seam in Parbatpur block at a depth of 795 m from the surface. The coal seams at greater depth (>500m) in the East Bokaro and North Karanpura Coalfields also contain substantial reserve of the gas. Methane content of coal seams in the Asnapani block of East Bokaro coalfields (far away from mining area) is about $7.0m^3/t$ at depth of 600m. Methane content of coal seams at depth of more than 500 m in Chano-Rikba and Ronhe Rautpara blocks of North Karnapura coalfields assessed recently to be 3 and 6 m^3/t respectively.

However, such indicative information is highly inadequate to estimate the potential of CBM. The estimation of availability of CBM is a complex, time-consuming, and capital-intensive process. For example, the number of drill holes needed for exploring CBM is 10 times that needed for natural gas. The time and cost involved in pumping out the associated water from CBM drill holes are also high. The quantum of gas is dependent on many parameters and some of them are highly variable. The data on the estimates of CBM reserve are, therefore, highly varied but all of them suggest a vast CBM reserve imbedded in Indian Coalfields ranging from 850 billion cubic meters to more than 1500 billion cubic meter. CBM potential of India as estimated by different authors can be summarized in Table 3 (Chand, 2001).

Table 3 Coal-bed methane resources estimated by various authors of Indian Coalfields

S.N.	Authors	Gondwana basin (BCM)	Tertiary (BCM)	Total (BCM)
1	Bastia et al. (1995)	837	13	850
2	Biswas (1995)	1000-1500	*	*
3	Peters and Jamal (1997)	*	*	1250
4	EGI Manual (1997)	*	*	8000
5	Reliance Industries Ltd (1999)	428.5	365	793.5
6	Directorate General of Hydrocarbons (1999)	595.92	939.3	1533.22
7	Government of Rajasthan	*	164	*

* Not reported

7. CBM EXTRACTION INITIATIVES IN INDIA

Investigation on CBM for its commercial exploitation is a comparatively recent phenomenon in India. After few preliminary studies by ONGC, GAIL, MECL, CMRI, CFRI, CMPDIL along with few private companies like Reliance, Modi Mcenzee, and Amoco from 1994-2000, Ministry of Coal started systematic investigation on CBM in Bengal-Bihar Coalfields with a UNDP grant of US$19.226 million. The Ministry of Coal has since started the work in several mines and adjoining areas. The project duration is 5 years (upto 2005) and is likely to generate more confidence in the prospective investors.

After shifting the CBM subject to Ministry of Petroleum and Natural Gas (MoPNG), CBM exploitation project was formulated by the Director General of Hydrocarbons with the help of the MoPNG. The project envisaged four phases: Phase I – Exploration (duration 3 years) Phase II - Pilot Assessment and Market Confirmation, (Duration 5 years, 7 years for frontier areas) Phase III – Development (5 years) and Phase IV – Production (Duration 25 years).

To start with Phase – I, it was proposed to outline commercially viable CBM blocks in consultation with Ministry of Coal (MOC) and offer them for international competitive bidding. MoPNG did a lot of home work and held three road shows – one in Delhi and other two in US, promising expeditious finalization of bids and a time-bound commencement of exploration activities for CBM.

Finally, First round of International competitive bid was floated in April 2001offering 7 blocks for exploration of CBM. The total area of these blocks is 2430 km^2 for 6 blocks of Gondwana and 410 km^2 of Tertiary lignite with a total estimated CBM resource of above 262.5 billion cubic metres. These blocks have an estimated reserve of high grade, high-to-medium volatile bituminous/sub-bituminous coal to the extent of 40.58 billion tonnes and 4.8 billion tonnes of lignite. The depth of burial ranges from 100 to 1500 metres for coal and 100 to 400 metres for lignite. The gassiness is estimated to be a minimum of 4 m^3/tonne and the maximum varies up to 15 m^3/tonne. Individual CBM Blocks details are given in Table 4 and are shown in Figure1.

The exploration of CBM, as mentioned earlier, is time-consuming and capital-intensive. Unless the offer is made attractive by fiscal and other incentives, the possibility of investors getting interested is remote. Keeping this in mind, many fiscal incentives have been offered with the bid viz. no signature bonus, no upfront payments, no import duties, unincorporated joint ventures permitted, no limitation on cost recovery, free to market gas in the domestic market at market-determined prices, securitization of participating interests allowed for raising project finance, no bank guarantee required for work programme at development stage, 7-year tax holiday, liberal set-off and accelerated deductions for income-tax purposes and no ring fencing.

Sixteen companies bid for this first offer of CBM blocks with Reliance (RIL) putting the maximum bid for six of the seven blocks on offer. Five CBM blocks were awarded in December 2001 with ONGC/IOC combine bagging two blocks, RIL- two and Essar Oil-one. Additionally, 2 blocks were awarded on nomination basis in 2003. One more contract was revived and signed afresh.

Encouraged by the success of first round of bidding of CBM blocks, MoPNG has launched a second round of bidding on May 23, 2003 (MoPNG, 2003) offering nine more CBM blocks having estimated CBM resource of 456.79 billion cubic meters spread over 5620 sq km area of different coal/lignite fields. The details of different blocks are given in Table 5 and are shown in Fig 2.These nine blocks are located in Andhra Pradesh (1) Chattisgarh (1) patially in Madhya Pradesh & Gujrat (1), Jharkhand (2) Madhya Pradesh (1) Maharastra (1) and Rajasthan (2).

8. CONCLUSION

Being the third largest producer of coal and having sixth largest coal reserve, India holds very good prospects for commercial production of CBM. Methane is a good option for CNG, petrol and diesel hence, its use, as fuel in vehicles will certainly help in reducing the pollution by road traffic. Till date, our country is not in a situation to fulfil the demand of even CNG for all vehicles. India is producing 6.5 billion cubic metre/day CNG, whereas the demand is 11.0 billion cubic metre/day. Therefore, the extraction of CBM will help in fulfilling the aforesaid demand. As already discussed, Indian coal reserves have a prospect for obtaining more than 850 billion cubic metre of coal bed methane. The recent initiative by Government of India by identifying and offering potential CBM blocks for its commercial exploitation will go a long way in reducing demand-supply gap in the energy, providing cleaner energy substitute and reducing green-house gas load of our atmosphere.

With signing of contracts for exploration of eight CBM potential blocks and offering of another 9 CBM blocks for bidding, India has entered for CBM exploration and production in a big way and is set to become the fourth after US, Australia and China to join CBM producing nations.

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Table 4-Details CBM Blocks Offered in First Round of Bidding

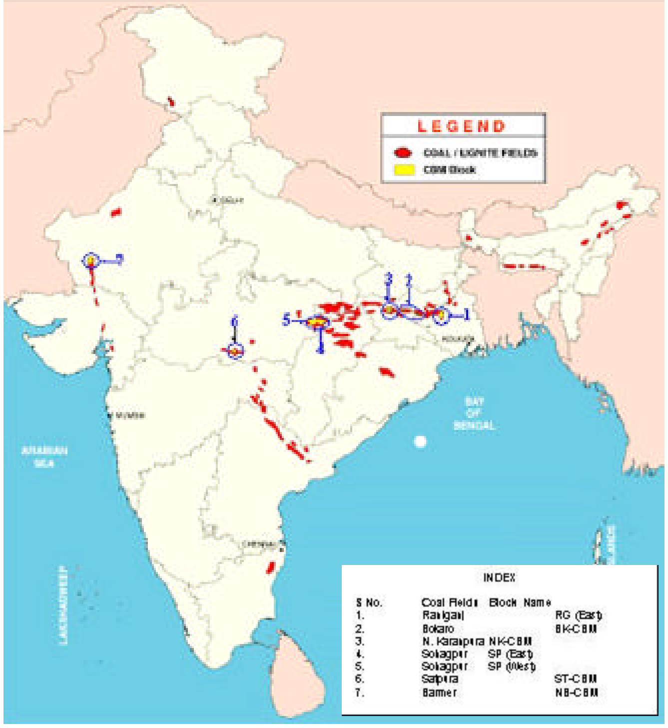
S.N.	Name of Coalfield/Basin	No. Blocks	Details of the Blocks	Geological area of the block (sq. km)	CBM Potential (BCM)
1	Raniganj Coalfield	One	Eastern part of Damodar valley group of Gondwana coalfields, Coal seams of Barakar (Lower Permian) formation- 6 seams of thickness upto 60m, gas content 3-8m^3/t and Raniganj (Upper Permian) formation- 10 seams of total thickness 60-70 m. Coal is high volatile, Bituminous 'A' with gas content 2-6 m^3/t,.	500	42.48
2	Bokaro Coalfield	One	In the East Bokaro Coalfields- 26 Coal Seams, thickness 3.8-36.6m, West Bokaro coalfields – 13 seams, thickness 3 to 23.8 m, coal of Barakar formation, gassy seams with history of methane explosion . Seams are high volatile bituminous-A to medium volatile bituminous with vitrinite reflectance of 0.8 – 1.2% and gas content 4-10 m^3/t	95	45.03
3	North Karanpura Coalfield	One	Western part of Damodar valley group of Gondwana coalfields. 5 Seams of Barakar formation-Seam I (20-25m thick) and Seam II(3.0-24.5m thick) are main targets for CBM. High volatile bituminous-A to medium volatile Bituminous coal with Gas content 6-8 m^3/t (vitrinite reflectance 0.9 to 1.44%).	340	61.74
4	Sohagpur Coalfield	Two	Two blocks SP(East) and SP(West) in South Rewa Gondwana basin. Seam III & V of Barkar formation are main CBM targets. High rank coal with vitrinite reflectance 0.78 to 0.99% indicates gas content of about 4 m^3/t upto 600-700m depth.	SP(east) -495	49
				SP(West) -500	36.82
5	Satpura Coalfield	One	Located along Narmada valley, Satpura basin lies in Kanhan-Tawa valley, Coal of high volatile bituminous 'A' to medium volatile bituminous with vitrinite reflectance 0.70 to 1.20% have gas content about 5 m^3/t. Few collieries of the coalfields are Degree III mines.	500	18.44
6	Barmer Basin	One	Barmer basin lies in Thar desert of Rajasthan. Block located in northern part of the basin (Shiv sub-basin) having lignite seams at shallow depth. Gas content 1.5 m^3/t. (Vitrinite reflectance –0.35%)	410	9.00

Note: BCM – Billion Cubic Metre

Table 5-Details CBM Blocks Offered in Second Round of Bidding

S N	Name of Coalfield	Nos of. Blocks	Details of the Blocks	Geological area of the block (sq. km)	CBM Potential (BCM)
1	South Karanpura Coalfield	One	Located in east-west elongated Gondwana basin. Barakar formation is main coal bearing within a sequence of 1050 m with most prospective seams in axial region of basin are Argada A+B (10-18m), Argada (12-13m), Sirka (4-15m) and Balkurda Seam(10-20m). Raniganj formation has 7 seams of 1-3 m thickness. Barakar seams corresponds to high volatile bituminous 'A' to medium volatile bituminous rank with vitrinite reflectance 0.7-0.9%. Gas content of seams ranges from 6-8m^3/t.	70	30.45
2	North Karanpura Coalfield	One	Westernmost member of east west chain of Damodar valley coalfields of eastern India. Barakar formation as main coal depository containing five coal seams Seam I (15-27m), Seam II (3.0-58m), Seam III (0.8-14m), Seam V (13-27m). Coal is high volatile bituminous 'B' to 'A' Rank with indicative gas content 4-5 m^3/t.	267	43.56
3	Sonhat Coalfield	One	Central part of South Rewa coal belt in Chattisgarh state. Barakar formation having eight regional seams (I to VIII) are the main coal depository. Coal is high volatile bituminous 'A' of moderately high rank with gas content of 5-6 m^3/t upto 600-700m.	825	33.89
4	Satpura Coalfield	One	Central part of Indian peninsula along the southern flank of the Narmada Valley. Barakar formation is main coal bearing horizon with five coal seams (1.0-8.0 m) in Pench area,top seam (1.1-4.8m) in Kanhan area and four seam (0.2-5.6m) in Patherkera area, Tawa valley are major CBM target. Coal is high volatile bituminous 'A' in rank with vitrinite reflectance of 0.65-1.02 upto depth of 600m. The coalfield has a number of degree III mines and indicative gas sorption capacity of 6.3 to 8 m^3/t.	714	29.32
5	Wardha Coalfield	One	Nothwestern part of Pranhita-Godavari Gondwana basin in Maharastra. Barakar formation with one thick composite coal horizon of 14.3 m thickness is the main coal bearing unit. Coal corresponds to high volatile bituminous 'C' to 'B' rank with vitrinite reflectance of 0.5-0.7 within 300m and gas content of 4-6 m^3/t.	503	19.9
6	Godavari Coalfield	One	North western part of Godavari Gondwana basin in Andhrapradesh. Barakar formation is the main coal bearing unit with dip side of extensive mining belt from Dorli-Belampalli to Ramgundam is the main CBM target area. Contains10 seams of 0.6-18.2 m thickness. Coal is high volatile bituminous 'B' with vitrinite reflectance of 0.6-0.7% and gas content 4-5 m^3/t.	386	29.65
7	Barmer	three	Lies in Thar desert of Rajasthan is norther extension of Combay basin. Three CBM block viz BS(1) in Western flank, BS(II) in Eastern flank of Barmer rift in Rajsthan and BS(III) in Gujrat portion of the basin. Extensive lignite deposite of upto 76 m thick seam. Low rank Lignite with vitrinite reflectance of 0.35% and gas content of 3-4 m^3/t.	*BS(1)* 1045	95.1
				BS(2) 1020	87.72
				BS(3) 790	87.2

Note: BCM – Billion Cubic Metre



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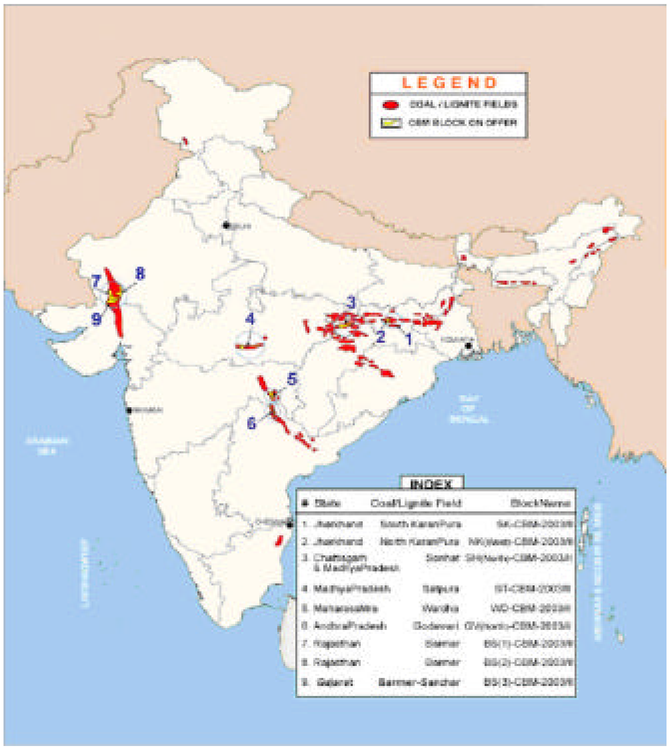
S No.	Coal Fields	Block Name
1.	Raniganj	RG (East)
2.	Bokaro	BK-CBM
3.	N. Karanpura	NK-CBM
4.	Sohagpur	SP (East)
5.	Sohagpur	SP (West)
6.	Satpura	ST-CBM
7.	Barmer	NB-CBM

Fig.1 Location of Feasible Coal Bed Methane Blocks in India During First Round of Bidding



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#	State	Coal/Lignite Field	Block Name
1.	Jharkhand	South KaranPura	SK-CBM-2003/II
2.	Jharkhand	North KaranPura	NK(West)-CBM-2003/II
3.	Chattisgarh & MadhyaPradesh	Sonhat	SH(North)-CBM-2003/II
4.	MadhyaPradesh	Satpura	ST-CBM-2003/II
5.	Maharashtra	Wardha	WD-CBM-2003/II
6.	AndhraPradesh	Godavari	GV(North)-CBM-2003/II
7.	Rajasthan	Barmer	BS(1)-CBM-2003/II
8.	Rajasthan	Barmer	BS(2)-CBM-2003/II
9.	Gujarat	Barmer-Sanchor	BS(3)-CBM-2003/II

Fig.2 Location of Feasible Coal Bed Methane Blocks in India During Second Round of Bidding