CHAPTER 1

Introduction

1.1 Background

Coalbed methane (CBM) has gained considerable ground as an unconventional source of energy in the recent past. CBM which was considered to be uneconomical and non-conventional only a few years back has now become very much attractive as a new energy resource. Specifically, for the countries like India where more than 75% of the total energy demand is accomplished from imported oil & gas, CBM can play the most important role to sustain its rapid pace of development.

Coalbed methane (CBM) is natural gas it is generated during coalification process and get adsorbed in coal at high pressure. CBM is rich in methane (88-98%) [Diamond et al., 1986] which emanates from coal due to change of in-situ pressure conditions.

Methane which is found in coal seams is named as coalbed methane. Large amounts of gases like methane, ethane, CO$_2$, water vapor, H$_2$S etc. are produced during coalification, and a portion of them is held both in the coal seams and adjacent rocks [Kim and Kissel, 1988; Patching, 1970]. Methane is the principal gas in this mixture. Methane, which is 23 times more potent green house gas (GHG) than CO$_2$ leads to mining hazard if not ventilated prior to coal mining operations. Thus, presence of CBM in underground mine not only makes mining works difficult and risky, but also makes it costly. On the other hand, CBM is a remarkably clean fuel when burnt with a heating value of approximately 8500 Kcal/Kg compared to 9000 Kcal/Kg of natural gas of power grid quality. Thus, CBM production not only can provide additional energy to fulfill more demand, but also help to reduce global warming to great extent. Enhanced recovery CBM by CO$_2$ sequestration can improve the situation.
Worldwide total coalbed methane potential have been estimated to be 89 trillion m$^3$ to 269 trillion m$^3$ of gas in place [Charles et al., 1998]. Countries like USA, Australia, China and India are currently producing CBM on an economic scale. USA is the largest CBM producer in the world and 1.91 TCF gas have been sold in 2009 [Pashin, 2011]. India holds the fourth largest proven coal reserves [Coal Atlas of India, 1993] and third largest coal producer country in the world. Indian coalfields are divided into two broad groups of two distinct geological ages: Gondwana coalfields of Permian age and Tertiary coalfields of Tertiary age. More than 98% of Indian coal production comes from Gondwana coals. These coalfields belongs to the Damodar valley (West Bengal - Jharkhand), Son - Narmada valley (Madhya Pradesh), Mahanadi Valley (Orissa) and Pranhita – Godavari valley (Maharashtra – Andhra Pradesh). Raniganj and Birbhum coalfield in West Bengal; Bokaro, Jharia, North Karanpura and South Karanpura coalfield in Jharkhand; Singrauli, Sohagpur and Satpura coalfield in Madhya Pradesh; Ib-valley and Talchir coalfield in Orissa; Korba in Chattishgarh and Wardha in Maharasatra are the most important Gondwana coalfields having vast reserve of good quality coal. Tertiary coalfields are Assam –Meaghalaya; Neyveli; Cambay; Barmer – Sanchor; Bikaner and Jammu & Kashmir. On the basis of coal rank, maturity, Physico-chemical attributes of coal, depth of occurrence of coal, available area and CBM potential, Indian coals are divided into four types: category-I, category-II, category-III and category-IV (Fig. 1). Jharia, Bokaro, North Karanpura and Raniganj coalfield belong to category-I type and comparable with global producing CBM fields in terms of gas content and adsorbed capacity [Hajra et al., 2003] for their good coal seam thickness, high rank and maturity. Damodar and Mahanadi valley coalfields are categorised as category-II and Category-III. The above mentioned Tertiary coalfields are placed in category IV as their CBM prospects are yet to be established.

India has started evaluating different coal-bearing sedimentary basins for their CBM potential in the early nineties [Patra et al., 1996]. Exploration and development of coalbed methane in Jharia and Raniganj coalfield have been going on for about last 15 years and being actively explored by different exploration and production companies. India has approximately 4.6 trillion cubic meter of CBM reserve [DGH report, 2009-10] which may fulfill the country’s future growing energy demand to a large extent. However, detail
information of Indian CBM field is lacking in literature. Jharia coalfield of Jharkhand, Raniganj coalfield of West Bengal and Singareni coalfield of Andhra Pradesh have been selected for evaluation of chemical parameters, gas content, gas adsorption capacity, gas saturation and recovery of gas by primary and secondary processes. In-situ gas content measurements have been performed for 2 coalfields, i.e., Jharia coalfield and Raniganj coalfield from the wells under drilling. Most of the fields are still under exploration stage while a few have just started production. In the present work, investigation have been carried out in 3 coalfields.

Fig. 1.1: Distribution of Coalfields and CBM blocks, India
The methane content of the above mentioned field mainly Jharia and Raniganj have been estimated by direct gas content measurement or Canister desorption test. A more general estimate can be made using adsorption isotherm data. Adsorption isotherm curves indicate that gas adsorption increases with increasing rank of coal at given temperature and pressure condition. Gas saturation and pressure at which gas can be started to release also determined from isotherm curves.

The initial recovery of CBM requires depressurizing through long time dewatering and massive hydro fracturing of coal beds. Gas and water are produced through cleats opening to the production well by lowering of pressure around the well and initially water production is more compared to gas production [Nuccio, 2000]. Gas start to desorb by reducing the pressure at the matrix-cleat interface and gas diffusion occurs through the matrix to the cleat [Gunter, 1997 and Law et al., 2003] and CBM is produced.

In India, production of methane from Indian CBM fields still is in preliminary stage. Advanced research is required for efficient recovery from these fields. In present few experimental works for enhanced coalbed methane recovery for Indian CBM fields have been presented by different researchers like Prusty B. K., 2008; Dutta et al., 2011; Vishal et al., 2013 and Bhowmik and Dutta 2013.

Worldwide few pilot scale projects for ECBM in different coal bearing basins like San Juan Basin in New Maxico and Colorado, Alberta Basin in Alberta, the Black Warrior Basin in Alabama, the Appalachian Basin in the eastern United States, Upper Silesian coal basin of Poland (RECOPOL project), China coal basin, Sydney Basin in Australia and coal basins in Japan [Reeves 2004, Gunter et al., 2004; van Bergen et al., 2003] are going on.

Till date, literature lacks on enhanced CBM recovery by CO$_2$ displacement technique from Indian fields. From the literature also, it is revealed that many Indian CBM fields require enhanced recovery technology for efficient production of methane. The initial recovery of CBM requires long time dewatering and massive hydrofracturing of coal beds. This leads to increase of the total project cost by several folds. CO$_2$ sequestration may be implemented to enhance the recovery of CBM. Moreover, Durgapur industrial area emits huge quantity of
CO₂ to atmosphere which can be utilized properly for efficient recovery of CBM. CO₂ sequestration process may reduce the cost by minimizing the need of fracturing.

On successful investigation, the developed technology may be implemented in enhancing the CBM recovery. Dewatering time and fracturing cost can be reduced by CO₂ sequestration. In addition to this, this process will reduce environmental pollution, thus helpful to combat global warming to some extent.

1.2 The objectives of this thesis are given below:

I. Chemical and petrographic study of the collected samples and evaluated CBM potential zone.
II. In-situ gas content measurement and isotherm study for evaluation of CBM potential
III. Determination of primary recovery of methane from experimental study & future prediction using Fekete CBM software based on Material Balance equation
IV. Laboratory investigation on recovery of CBM by CO₂ injection
V. Data analysis & Optimization of the primary and enhanced CBM recovery using Eclipse simulator based on Black-Oil model.
VI. Prediction of water production in CBM wells

1.3.0 Methodology:

1.3.2 Selections of study area and its geology. The coalfields have been selected in the present study and geology have been investigated. Different geological aspects like lithology, stratigraphic succession, and geological structure, i.e., fault, joint, fractures etc. have been discussed here as these parameters play very important role in reserve and its production. Effects of these parameters on occurrence of coal in CBM basin, generation of methane and its retention capacity of the coal have been explained in detail. This chapter also incorporates the feasibility study of CO₂ sequestration techniques based on the geology of the areas under investigation.
1.3.3 Petrographic study: This chapter describes the procedure for sample collection from the CBM field, preparation of sample for analysis, experimental setup and methods for the present investigation. Descriptions have been made for the determination of rank of coal from proximate, elemental and from petrographic studies. Detailed analyses on 42 coal samples collected from 3 different locations of Jharia coalfield, 10 samples from 2 locations of Raniganj coalfield and 10 coal samples from Singareni coalfield have been performed in the laboratory. Proximate analysis, chemical analysis, and petrographic study were carried out on these samples because these are the key parameters in identifying the prospective coalbeds for economic amount of methane content.

1.3.4 Discuss about the gas content measurements (i) In-Situ gas content measurement in the drill site and (ii) adsorption isotherm study in the laboratory. This chapter clearly describes the procedure for measurement of in-situ gas content, description of volumetric apparatus and isotherm study. Is-situ gas content of coal samples were measured from canister desorption test at well drill-site. The range of gas content for Jharia coalfield fall within and above the range of economic limit and should be the targeted as suitable zone for CBM extraction.

The gas adsorption capacity, reservoir pressure, critical desorption pressure and gas saturation of selected coal samples have been determined from the isotherm study using isotherm apparatus.

In the present study, various adsorption isotherm models were tested with the experimental data and best fit model is considered. Sorption data obtained from adsorption isotherm study were fitted with the various isotherm models and their absolute error and regression values are compared to determine best fit one. The gas content in coal determined by field desorption study and adsorption study are different.

1.3.5 Describes the primary recovery process, gas transport mechanism through the coal cleats, gas reserve estimation and simulation study. The material balance equation and volumetric method are used for gas reserve estimation. The Fekete CBM software is used to predict the future production of gas and water. The simulation study shows that longer dewatering is required to start gas production; rate of production is also less due to low
permeability of the reservoir. To enhance production rate, fracturing of coalbeds is
essential. Multilateral wells like Z-Pinnate type also may increase the accessibility of wells
to larger area (e.g. Jharia field) and thus can enhance the production rate.

1.3.6 Consists of comparative study on primary and enhanced CBM recovery by CO$_2$
injects and effects of various parameters like pressure, wells spacing and pattern, water
saturation and injection pressure on this. Laboratory investigation as well as simulation
studies have been carried out using Eclipse simulator. The process has been optimized
considering various economic and technical parameters.

1.3.7 Covers the prediction of water production studies. This has high impact on the
recovery of the methane from reservoir because inefficient dewatering of CBM reservoir
can damage the coalbeds and hence the fluid flow network path. The effects of water level
to production rate have been discussed. A new mathematical correlation is developed for
predicting water production rate from dynamic water level which is much simpler
compared to conventionally used type curve analysis.