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General Research Paper

Coal Bed Methane Exploration: A Journey from Alternative Energy Option to the Environment Polluting Agent

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ABSTRACT

The occurrence of methane gas in the underground coal seams is well known since last many decades, but its pre-mining recovery in the form of CBM technology has been established in the recent times. Coal bed methane, no longer an emergent resource, is now maturing as a significant source of energy for mitigating the enhanced energy requirements of the world including India. The dual benefits of CBM recovery, other than alternate energy option include reduction in mining hazard and green house effect. But, the actual field experience of CBM exploration reveals that the technique is accompanied with many environmental difficulties like groundwater depletion, water disposal problem, air pollution, soil degradation and adverse effects on the ecosystem etc. As a result, the regulatory bodies involved in such programs are facing the challenge of balancing the need to fulfil the projected energy demand on one hand and their duties to protect the environment on the other. Present paper focuses on the environmental hazards and their possible remedial measures vis-a-vis CBM technology.

INTRODUCTION

Coal is derived from the plant remains that have been compacted, hardened, chemically altered and metamorphosed by the enhanced pressure and temperature (P-T) conditions over the periods of time (Statch et al. 1982, Rice 1997, Chandra et al. 2000, Varade 2001, Acharya 2001, Thakre, 2007, Varade et al. 2009). In this process of coalification, methane, H_2O and several other gases are evolved (Parivesh 1999, Rice et al. 2000, Singh & Singh 2001, WORC Fact Sheet 2003). Methane gas, formed as a byproduct of coalification process and remained entrapped within the coal seams is termed as ‘Coal Bed Methane’. The CBM technology aims at producing coal bed gas by making surface boreholes in virgin coal bearing blocks and subsequently using the recovered methane as a valuable fuel resource. Methane is a combustible gas with high heating value of~8500-8900 kcal/m^3 compared to 9000 kcal/m^3 of natural gas and can be used as a valuable fuel resource for commercial and other industrial purposes (Mendhe & Singh 2003). In the recent times, this method has been widely recognized all over the globe not only as a fuel resource in decreasing green house effect but also as a clean technology (USEPA 1998, Varade 2001, Chand 2001, Mendhe & Singh 2003).

THE ENVIRONMENTAL CONCERNS

The CBM exploration, exploitation and development activities are accompanied with several environmental hazards. In the following paragraphs the pollution impacts involved in the process of CBM technology are discussed.

Aquifer Contamination

The amount of methane produced during the coalification process generally exceeds the gas holding capacity of the coal seams (Varade et al. 2009). As a result, the additional gas migrates into the surrounding rock formations (Chafin 1994). The fissures, joints, secondary openings in the natural rock provide the natural conduits for migration of methane gas. Similarly, the uncemented annular spaces left behind the existing well casings, water wells, and improperly abandoned oil and gas wells also stimulate towards the migration/seeping of the methane gas. While seeping, methane contaminates the overlying groundwater aquifers and also kills the vegetation (Sircar 2000, USGS Fact Sheet 2000). The enhanced levels of methane present in basement and drinking water leads to undesirable health hazards of several families (Rice 1997).

Dewatering of Aquifers

Methane gas is tightly held in the coal seams by the hydrostatic pressure exerted by groundwater, and its production increases with decrease in its water content (Rice 1997, Rice et al. 2000, Varade et al. 2009). Therefore, in order to lower the pressure in the coal bed reservoirs and to stimulate the release of methane from the coal seams, the early stage of CBM production requires pumping out of billions of gallons of groundwater to the surface (Sircar 2000, USDE 2002). This de-pressurization of aquifers results into formation of cone of depression and the drastic depletion in the groundwater levels of the adjacent dug and bore wells (Shuey 1990, Beckstrom & Boyer 1991, Bureau of Land Management 1999, Kurz & Sorensen 2002).

Water Disposal Problems

The pumped water removed off from the CBM wells forms a critical problem with respect to its disposal (Newell & Connor 2006). This water filled within the fractures, cleats, permeable zones of coal beds is saline and usually contain high concentration of dissolved salts and solids along with the elevated levels of fluoride, ammonia, sulphate and other elements (Follett & Soltanpour 2001, NPRC 2003). Most commonly the produced water is discharged over the ground surface or poured into the adjacent streams/rivers (USGS Fact Sheet 2000). The increased quantity of surficial flow not only reflect its impact on the water quality of the stream/river, but also increases the rate of stream channel erosion and sediment load and poses potential negative effect on the vegetation pattern of downstream irrigators (i.e., flooding of agricultural land) and aquatic organisms existed in the river ecosystem (Flores et al. 2001). Similarly, the same waters if contain a high ratio of sodium to calcium and magnesium (i.e. Sodium Adsorption Ratio/SAR) prove deleterious to soils and vegetation pattern of the area. Further, the elevated ratio of sodium to calcium and magnesium also alters the chemical composition of clays and reduces the soil permeability.

Flaring of Gas

The flaring of gas into the atmosphere is generally considered as an acceptable means of disposal. However, due to the improper burning practices catch fire like situation may take place at the well site.

Air Pollution

The use of internal combustion engines to drill and service wells, compress gas, and transportation produce emission of several gases like N_2O, CO, SO_2, CO_2, particulate matter and toxic air pollutants and pose an adverse impact on air quality of the area. To accommodate the large volume of extracted methane, the setting up of additional processing plants is required. Establishment of such processing plants results into the emission of CH_4 and CO_2 like gases in the environment (Bureau of Land Management 1999). Similarly, the fugitive dust and exhaust from construction activities along with air pollutants emitted during various well operations, etc. create non-conducive environment at the site.

Noise Pollution

For the production of CBM from the underground coal seams various well site equipments are required. The noisiest aspect of CBM development is to compress the gas in a compressor. Although the noise generated by these equipment is often of low intensity, the humming can be an aggravation to those living in the nearby areas (Parker 2000). The heavy vehicle traffic on access roads produces noise and disrupts the nesting patterns for birds, fish spawning, animal migration and peace-of-mind of human community (PRBRC 2000).

Surface Disturbances

The construction and operation of wells requires a network of access roads, drilling sites, pipelines, power lines, compressor stations and containment pits. Establishment of such facilities disturbs the surface, and in the case of roads creates easy access to areas that were formerly difficult to reach. A complete alteration in the landscape pattern of the area may take place due to the extensive and rapid development program (Bureau of Land Management 1999).

SOME REMEDIAL MEASURES

The measures which can significantly decrease the CBM development and production associated environmental challenges are discussed below;

Methane Venting

Scientific investigations on geological, hydrological and structural aspects of sub-surface lithologies help to evaluate specific litho-units with respect to their technical aspects like porosity, permeability and structural details. Such approaches helps to identify a proper cementing and monitoring system to be installed at the well completion process and facilitate reduction in the methane seepage (USDE 2002).

Re-Injection of CO_2

The adsorption of CO_2 molecules by coal seam stimulates desorption of methane and thus enhances its production. This characteristic of CO_2 gas can be significantly used for the enhanced or secondary recovery of CBM from the coal seams. The CO_2 drawn from power plant waste streams can be effectively used to inject into the coal seams. The duel benefit of the technique facilitates the enhanced methane recovery and reduction in the green house effect (Bryner 2002, Youngson 2007).

Flaring

The fire related problem nearby the well site can be reduced by adopting specific precautionary measures such as wetting down the areas and ensuring adequate bearing of flare.

Water Treatment Methods

The environmentally acceptable water disposal options of produced water from the wells are a major environmental concern in the CBM development process. However, following techniques may prove effective in dealing with the treatment of CBM produced water (Ogbe 2000).

Direct discharge to land surface: Mixing up of high SAR water with better quality low SAR water like water management practice may definitely help to minimize the soil damage and allow for much of the soil of the area to be irrigated.

Deep injection: The direct injection of the produced water into the deep subsurface formations provides another alternative option of water disposal. Few advantages of this technique involve reduction in the further erosion of the surface soil, degradation of surface water and groundwater, etc.

Impoundment structures: The impoundment structures built for the disposal of CBM produced water includes evaporation/infiltration ponds, storage ponds with discharge to surface waters and construction of wetlands treatment (DOE techline 1997).

***Infiltration/Evaporation*:** The produced water stored in the artificially created infiltration pond is allowed to infiltrate back into the ground. This downward moving water, under the action of gravity eventually meets the water table level and maintains the water levels in the area. Likewise, the natural process of evaporation reduces the stored water in the associated evaporation ponds.

***Atomization treatment*:** The process of separation of water particles into small droplets and its dispersion may prove to be very effective in warm dry climatic areas, where droplets can easily be evaporated than water stored in impoundments.

***Freeze-thaw/Evaporation*:** In the cold climatic conditions, where the freezing temperatures for several consecutive months are experienced the produced water may be allowed to freeze naturally. The dissolved solids and other constituents are concentrated in the unfrozen liquid state with the process of water freezing. The ice that is formed is higher quality water than the produced water from which it was derived. This ice can be collected and thawed to provide a source of high quality water. The process can be repeated until the more concentrated effluent of a manageable volume is obtained. This smaller volume of effluent, though more concentrated, can be more easily disposed.

Reverse osmosis (RO): The technology involves removal of the total dissolve solids (TDS) and other constituents of the produced water. Water is removed from a solution containing dissolved solids by passing it through a semi-permeable membrane. As pressure is applied, the semi-permeable membrane allows water to pass while the membrane retains the dissolved solids. The membranes are often cleaned by a cross flow which removes the molecules retained on the surface; these molecules are then collected and concentrated for disposal. This can be used to treat produced water and concentrate constituents into an effluent that is smaller in volume and more easily disposed off.

Ultraviolet sterilization (UV): The technique covers removing of the unwanted free-floating constituents (mainly microscopic organic contaminants) from the produced water. The sterilized water can be re-injected into an aquifer and used for groundwater restoration, aquifer storage and recovery, or aquifer recharge.

Wetlands: Wetland plants can remove some dissolved constituents from water, reducing the concentration levels in the water and binding the constituents within the plant structure. This treatment helps in reducing the concentration of dissolved sodium and other metal constituents of produced water by the natural action of biologic reactions.

Chemical treatment: The chemical treatment can effectively remove the disease-causing bacteria, nuisance bacteria, parasites and other organisms, etc. This chemically treated water can be further used to oxidize iron, manganese, and hydrogen sulfide for filtering these minerals from the water and the produced water can be utilized for the human consumption after the process of chlorination (USDE 2002).

Air quality: The air pollutant emission during construction can be controlled by applying water or chemical surfactants on the disturbed soil. Using CBM-burning engines, electrical compressors also reduce the emissions and level of exhaust.

Noise quality: The local governments can reduce conflicts over noise from CBM development by imposing zoning restrictions on noisy activities such as gas compressors in sensitive residential, commercial or institutional areas; using industrial form development permit areas to deal with siting; and establishing noise bylaws to place restrictions on noisy activities and noise levels. The noise pollution can be substantially minimized by imposing speed restrictions on all project vehicles, using acoustic enclosures on the equipment and by using the soil berms to help attenuate noise sources like techniques. The gas-powered compressors that move the gas along the transmission pipelines should be equipped with strict sound-reduction systems. The noise impacts can also be reduced by using the electrical compressors.

Wildlife protection: The effect of CBM development on wildlife occurs primarily at the time of well site construction, pipeline networking, etc. Such effects can be avoided by fencing of the well facilities and underground burring of the pipeline system at the end of well completion process. Similarly, the reclamation methods like re-contouring, replacement of topsoil, planting of native species adopted at the end of well completion can also reduce the hazards (Elcock & Gasper 1999, Regele & Stark 2000).

CONCLUSION AND RECOMMENDATIONS

In the present energy scenario, CBM technology due to its manifold advantages has attracted the active attention of various governmental and private agencies, policy makers, scientists and technologists of the world including India. It is beyond dough that the CBM recovery and its commercial utilization will play a vital role in fulfilling the enhanced energy requirements of the world. However, the field experience demonstrates that the process of recovery of methane gas from the underground coal seams imparts into several environmental concerns. Therefore, in order to maintain a sustainable balance between environment and the technology, designing and implementation of an appropriate management policy/plan is required. The primary objective of such policy should confined to balance the environmental, economic and community interests. The objectives of this plan will be to provide a proven way of conducting CBM operation, eliminate or minimize adverse impacts from the related CBM technology to the public health and the environment, enhance the value of natural and landowner resources and reduces conflicts.

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