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Assessment of Plant Species for Phytoremediation of Coal Bed Methane Product Water in Singrauli Coal Field, M.P.

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ABSTRACT

Coal-bed methane (CBM) has been accepted as an environmental friendly fuel globally. The Singrauli coal field of Madhya Pradesh with thickest coal seam is the main center of CBM production in India. However in recent years the CBM product waters resulting from extraction of methane from coal seams have become a matter of great concern for the ecology of the region. CBM discharge waters have shown a great impact on soil physical and chemical properties by increase of salinity and sodicity within local soil ecosystems and on vegetation diversity. It is hypothesized that some plant species can function to absorb excess salts resolving the saline-sodic conditions associated with CBM discharge water. This research was carried out to assess and identify the suitable plant species surviving in the area for phytoremediation of the saline-sodic soil in Singrauli District. Altogether 26 plant species has been evaluated which shows highest degree of survivability in saline-sodic soil in the region. The result reveals that among ion accumulator or excretors, 2 plant species were found as ion accumulator, 3 species as ion excretors, 1 species as increasing soil pore size and 2 species were limited ion accumulator. The studies on survivability and tolerance suggests that 7 species shows high salt tolerance capacity, 10 spp. were found to be high sodium tolerance, 5 flood tolerances and 7 spp. shows high pH tolerance capacity. The evaluation and recommendation of the suitable field crops and trees can improve the soil ecology and also enhance the economy of the poor and marginal farmers in the region.

***Key words**: Coal-bed methane, salinity, sodicity, phytoremediation*

Introduction

The global energy demand is increasing rapidly and has elevated in the last decades or two. Therefore the modern world needs a lot of energy for sustainable development; which cannot be fulfilled by conventional resources such as Coal, oil and gas. It becomes more difficult for those countries that are deficient in coal resources or have exploited their shallow coal deposits in last two/three decades and have no option but to go for other source of energy for meeting their requirements. However the advent of new technology for Coal Bed Methane, has given a ray of hope to exploit the deep-seated coals to meet the future energy demands (Chappll and Mostade, 1998). Coal-bed methane (CBM) is natural gas found in coal seams. It is formed naturally as a byproduct of the geological process that turns plant materials to coal. CBM is considered an unconventional form of natural gas because the coal acts both as the source of the gas and the storage reservoir.

The Madhya Pradesh state of India has Coal reserves of 16027.07 million tonnes which is 7.71% of total Coal reserve of country. In Vindhya region of Madhya Pradesh, Sidhi, Singrouli and Shahdole district are the chief Coal producing areas. The country's thickest coal seam viz Jhingurda ; which is 135 m thick, occurs in the Singrouli Coal Field of Northern Coal Field Limited. This region has also adopted the production of alternative fuel instead of coal through Coal bed Methane (CBM). The technique offers a method of extracting methane from coal without affecting the physical properties of the coal. CBM, is a clean alternative fuel to replace brown, hard coals and coke oven gas, and is an environmentally friendly fuel. Therefore the coalbed methane (CBM) has emerged as one of the new clean energy resource instead of coal and natural gas in the country in general and in this region in particular.

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However, the concern about coal bed methane (CBM) development is the impact that CBM product water could have on green plants and ecology in the region. The extraction of coal-bed methane involves drilling a hole of about 200 - 1500 meters into a coal seam. As a result some amount of water from the coalbed get pumped causing decline in the pressure within the coal seam, and the gas and 'produced water' escape to the surface through tubes. The gas reaches to a compressor station and further to natural gas pipelines. The 'produced water' is either released into streams or pumped back in the ground. This 'methane water' mainly contains sodium bicarbonate and chloride and is saline-sodic in nature and if left untreated, it pollutes ground water. The untreated or disposed water enhances the saline-sodic conditions of the soil, causing decreases in forest and agricultural productivity. CBM product water quality is typically associated with elevated salinity and sodium hazards (USDI-BLM, 1999; Phelps and Bauder, 2001; Rice *et al.,* 2002). The discharged water adds salinity, mainly in form of sodium, in the region that already contains a high amount of geologically derived sodium, thus effecting plant yields or even its mortality (Hanson *et al.,* 1999).

The Phytoremediation, which utilize specific planting arrangements, constructed wetlands, reed beds, floating-plant systems and numerous configurations, has emerged an effective techniques in treating wastewater, and contaminated soils and atmospheric pollutants as well (Cunningham *et al.,* 1995; Anonymous, 1998). The selected plant community types, functioning as salt tolerant halophytes, ion accumulators/excretors, and species that tend to promote soil permeability, combined with accurate water management strategies, have potentiality in minimizing negative effects of elevated CBM product water salinity and sodicity. Remediation is best considered a long-term process since it is usually slower compare to chemical treatments; as the levels of targeted parameters is within the tolerance limit of the selected plants; and involve a better control of highly soluble contaminants which may leach out of the root zone (Cunningham *et al.,* 1995). Metal tolerant plants may reduce the accumulation of metals in aboveground biomass, as well as delay phytotoxic responses (Bleeker *et al.,* 2002). Certain plant species have salt glands which maintain adequate osmotic potentials by extruding salts; others have mycorrhizal fungi on roots which are thought to enhance salt tolerance (Uchytil, 1990). Plants that are able to accumulate sodium salts could be used successfully to remove sodium from the substrates they are grown in (Helalia *et al.,* 1990). The halophytic plants were found effective to desalinate soil and water (Boyko, 1966). Earlier, laboratory and field investigations of plants growing in extreme environments suitable for phytoremediation in saline sites has been attempted (Holmes, 2001). This research is therefore undertaken to assess native plant species that are best suitable for phytoremediation and tolerance to salinity, sodicity, and flooding associated with management and disposal of CBM product water.

Material and Methods

Study sites: Singrauli is the 50th district of Madhya Pradesh State of Union Republic India. It was granted district status on 24th May 2008, with its headquarter at Waidhan. Singrauli is located 24o 0' to 24 o 10' North latitudes and 82 o 05'to 82 o 23' East longitudes. It has approximately 2200 Sq.kms. of coalfield area and nearly 330 Sq. kms. CBM block area. The site surveyed was conducted and the plant species were identified that were surviving in the Coal Bed Methane Block area. The plant species were classified into four categories as-Ion accumulator, Ion excretory, soil pore size appetizer and limited ion accumulator species. The plant species were also categorized on the basis of their survivability and tolerance into 4 groups- Salinity Tolerance, Sodium Tolerance, Flooding Tolerance and pH/Alkalinity Tolerance. Two frequently used salt tolerance rating systems (Miller and Donahue, 1995 (Table 1(a) Maas, 1993 (Table 1(b)) were adopted to categorize the plant species.

Table 1(a): Salinity tolerance ratio (Miller and Donahue, 1995)

	Salinity tolerance level	Salinity tolerance ratio
1	Few plants affective	0-2
2	Some sensitive plant affected	2-4
3	Many plants affected	4-8
4	Most crop plant affected	8-16
5	Few plant tolerant	More than 16

Table 1(b): Salinity tolerance ratio (EC_e^1 (dS/m) Mass, 1993).

	Salinity tolerance leve	Salinity tolerance ratio	Symbol
1	Sensitive	Less than 1.5	S
2	Moderately Sensitive	1.5-3.0	MS
3	Moderately tolerant	3-6	MT
4	Tolerant	6-10	T
5	Very tolerant	More than 10	

The plant species' tolerances to sodicity (Sodium tolerance), may be expressed as SAR (sodium adsorption ration), ESP (exchangeable sodium percentage) or specific sodium concentration. On the basis of Sodium tolerance the plant were categorized into 3 groups- Extremely sensitive, Very tolerant and Data not available to justify a rating. (DPI Website, 2002)(Table 2).

Table 2: Sodium Tolerance rating (DPI Website, 2002)

	Sodium tolerance level	Symbol
1	Extremely Sensitive	ES
2	Very Tolerant	VT
3	Data not available to justify a rating	No Data Available

Flooding tolerance plant species are categorized into three groups-Intolerant: Unable to withstand flooding for more than a few days, Moderately tolerant: Able to withstand short-term flooding, approximately two weeks in duration, but not long-term flooding, and Tolerant: Able to withstand relatively long-term flooding, up to one year or more, but may still be damaged by consecutive years of flooding (Warrence *et al.,* 2003) (Table 3)

Table 3: Flooding Tolerance rating (Warrence *et al.,* 2003)

	Flooding tolerance level	Symbol
1	Intolerant	I
2	Moderately Tolerant	MT
3	Tolerant	T

PH/Alkalinity Tolerance Ratings of plant species were on the basis of (Warrence et al., 2003)

Results

The area was surveyed and altogether 26 plant species has been identified. They were specified and tabulated on the basis of ion accumulator/excretory and tolerance capacity. The result reveals that 2 plant species were found as ion accumulator, 3 species as ion excretors, 1 species can act as increasing soil pore size and 2 species can act as limited ion accumulator (Table-4).

Table 4: List of Plant species showing Ion accumulator/excretory properties

Common/Local Name	Scientific Name	Family	General function
Rice	*Oryza sativa*	Poaceae	Ion accumulator
Sunflower	*Helianthus anus*	Asteraceae	Ion accumulator
Salt Cedar/Farash	*Tamarix articulata*	Tamaricaceae	Ion excretory
Goosefoot/ Bathua	*Chenopodium album*	Amaranthaceae	Ion excretory
Kochia	*Bassia scoparia*	Chenopodiaceae	Ion excretory
Jowar	Sorghum vulgare	Poaceae	Soil pore size appetizer
Wheat	*Triticum aestivum*	Poaceae	Limited Ion accumulator
Barley	*Hordium vulgare*	Poaceae	Limited Ion accumulator

The plant shows significant variations regarding various tolerance capacities. Among the salt tolerant plant species 6 were found to be Tolerant, 4 species were found to be moderately tolerant, and 7 were found to be moderately sensitive (Table 5). The coal mine areas also possess sodicity tolerance plant species. The study indicates that among the observed plant species 10 species comes under very tolerant category and 6 were found to be Extremely Sensitive. Flood tolerance plant species shows remarkable variations at the study sites (Table 5). Among the observed plant species 5 species were found to be tolerant, 6 species were extremely tolerant and 1 plant was found to be intolerant. pH/ Alkalinity tolerance plant species also shows significant variations in CBM areas. All the 20 plant species can tolerate high to moderate to low pH range. Among the observed plant species, seven can tolerate pH more than 10, four species can tolerate pH in the range of 9 to 9.5 and nine species can survive in the pH ranging between 4.8 to 8.0 (Table 5).

Table 5: List of Plant species with various types of tolerance capacity

Common /Local Name	Scientific Name	Family	Salt Tolerance	Sodium Tolerance	Flood Tolerance	pH Tolerance
Khejri	*Prosopis Juliflora*	Fabaceae	T	SAR 1.6-8.0	No Data Available	10.3
Babool	*Acacia nilotica*	Fabaceae	T	SAR 1.6-8.0	No Data Available	10.4
Barseem	*Trifolium alexendrum*	Fabaceae	MS	No Data Available	No Data Available	4.8-7.9
Salt Cedar	*Tamarix articulata*	Tamaricaceae	T	SAR 1.6-8.0	MT	10.4
Beach Oak	*Casuarina equisetifolia*	Casuarinaceae	T	SAR 1.6-8.0	MT	10
Mint	*Mentha arvensis*	Lamiaceae	MS	SAR 1.6-8.0	No Data Available	4.8-7.9
Neem	*Azederachta indica*	Meliaceae	MS	ES	MT	6.5-8.0
Palas	*Butea monosperma*	Fabaceae	MT	SAR 1.6-8.0	T	9.4
Date palm/ Khazoor	*Phoenix paludosa*	Arecaceae	T	SAR 1.6-8.0	T	10
Portia tree/ Paras Pipal	*Thespesia populneae*	Malvaceae	MS	No Data Available	No Data Available	4.8-7.9
Karanj	*Pongamia pinnata*	Fabaceae	MS	No Data Available	No Data Available	4.8-7.9
Eucalyptus	*Eucalyptus spp.*	Myrtaceae	MS	ES	MT	4.8-7.9
Poplar	*Populus* euphratica	Salicaceae	MS	No Data Available	T	4.8-7.9
Thorny Bamboo	*Bambusa arundinacea*	Poaceae	MT	SAR 1.6-8.0	MT	9.5
Wheat	*Triticum aestivum*	Poaceae	No Data Available	ES	No Data Available	6.0-7.1
Rice	*Oryza sativa*	Poaceae	No Data Available	ES	No Data Available	6.4-7.2
Jayanti	*Sesbania sesban*	Papilionacae	MT	ES	MT	9.5
Psyllium/Isabgol	*Plantago ovata*	Plantaginaceae	MT	ES	I	9.5
Milk Bush	*Euphorbia tirucalli*	Euphorbiaceae	T	SAR 1.6-8.0	T	10
Brown Beetle grass	*Leptochloa fusca*	Poaceae	T	SAR 1.6-8.0	T	10.4

Discussion

The remediation of saline-sodic soil of CBM product water has been attempted in the past. Kirkpatrick *et al*. (2005) suggested a possible strategy to aid in processing CBM product water by constructing a wetland composed of a variety of halophytic plants which have dense fibrous root systems, uptake salts and sodium, that can be used as forage, and have high ET and water use rates, or a combination of these traits. Wali, (1999) measured vegetation on reclaimed coal mine sites of differing ages (1, 7, 17, 30, and 45 years) and observed that plant species richness increased from the youngest site to the oldest; suggesting that in the early stages of reclamation, focus must be given on cover of a few species rather than on establishing high richness and diversity. Negri *et al.* (1997)

suggested the use of a plant-based system that helps in water treatment from salt concentration and optimize metal uptake and reduce the volume of water produced by oil and gas wells.

The ion accumulators take up high concentrations of ions as an adaptation mechanism to saline environments (Phelps and Bauder, 2001). The accumulation of salts by the plants shows adverse impact on leaf thickness, wall extensibility, and water permeability that maintains positive growth and turgor at low soil water potentials (Rush and Epstein, 1981). Two ion accumulators that have been repeatedly referenced in the scientific literature are rice (*Oryza sitiva*) and sunflower (*Helianthus annuus*). Rice cultivation has been recognized to improve saline soils. (George, 1967) reported that the rice plant does contribute to soil improvement by accumulating salts in its shoots. Bhatt and Indirakutty (1973) observed that Sunflower plants can remove 83 kg of sodium from one hectare of land via accumulation. Phelps and Bauder (2001) observed that ion excretor halophytes possess glandular cells or vesiculated trichomes that have capacity in excreting sodium and other salts from leaf tissues. Kelly *et al.* (1982) reported that Tamarix species (salt cedar) and Atriplex species (saltbush) possess salt excreting glanular cells and trichomes, respectively.

The physical characteristics of rooting can also increase soil permeability and result in leaching of salts beyond the root zone. Decomposition of root resulted free channeling for water movement, and thus increases hydraulic conductivity of the soil (Phelps and Bauder, 2001). The interseeding plants Barley (*Hordium spp.*) and rice have potentiality in accelerating reclamation and bioremediation process (Saraswat *et al.,* 1972). The extensive root system of paddy rice loosened the soil, making it more permeable to leaching of salts (Yadav, 1975). The study is also in close conformity of Skidmore *et al*. (1986) who reported that Sorghum (*Sorghum spp.*) increases soil pore sizes and water infiltration and leads to greater saturated hydraulic conductivity.

Tisdale (1985) proposed that reductions in crop yield could be assigned to one of four categories of sodic soil, along with a corresponding ESP (%) and SAR. Qadir *et al*. (2001) evaluated phytoremediation techniques on a calcareous salinesodic soil (EC=24-32 dS/m, SAR=57-78 in top 0.15 m depth) planted with wheat (*Triticum aestivum* L.) in winter and rice (*Oryza sativa L.*) in summer, and irrigated with sodic and moderately saline water (EC=2.9-3.4 dS/m, SAR=12-19.4). After one crop each of wheat and rice, the final surface EC values were about 10 +/-1 dS/m in all treatments. The SAR for the profile to 1.2 m depth was reduced from ~31 to ~15 in all treatments, indicating that a significant amount of the excess sodium in the soil was leached below the 1.2 m depth. Ashok kumar (1996) reported that the grass *Leptocloa fusca* shows better response on salt-affected soils as it can tolerate extremely saline and alkaline conditions. It is also well adapted to the water logging encountered on saline and alkaline soils, and improves the soil's physical, chemical and biological properties. It excretes salts through specialized glands and is therefore reasonably palatable to farm animals.

Conclusion

The CBM product water has great impacts on ecology, pedology, vegetation, animal and human community surrounding the discharge areas. Therefore the plant species which functions as toxic ion accumulator or excretors should be raised in the region. The species selected should also help in phytoremediation of saline-sodic conditions. The application of new technologies in conservation of environment as a whole is strictly recommended.

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