

Fungal degradation of coal as a pretreatment for methane production

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HIGHLIGHTS

- ▶ Fungal isolate MW1 liberated complex organic compounds from coal matrix.
- ▶ MW1 was isolated from a core sample of coal.
- ▶ Variety of aliphatics, aromatics and aromatic nitrogen compounds were identified.
- ▶ Methanogenesis of released organics generated significant methane in some samples.

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ABSTRACT

Coal conversion technologies can help in taking advantage of huge low rank coal reserves by converting those into alternative fuels like methane. In this regard, fungal degradation of coal can serve as a pretreatment step in order to make coal a suitable substrate for biological beneficiation. A fungal isolate MW1, identified as *Penicillium chrysogenum* on the basis of fungal ITS sequences, was isolated from a core sample of coal, taken from a well drilled by the US. Geological Survey in Montana, USA. The low rank coal samples, from major coal fields of Pakistan, were treated with MW1 for 7 days in the presence of 0.1% ammonium sulfate as nitrogen source and 0.1% glucose as a supplemental carbon source. Liquid extracts were analyzed through Excitation–Emission Matrix Spectroscopy (EEMS) to obtain qualitative estimates of solubilized coal; these analyses indicated the release of complex organic functionalities. In addition, GC–MS analysis of these extracts confirmed the presence of single ring aromatics, polyaromatic hydrocarbons (PAHs), aromatic nitrogen compounds and aliphatics. Subsequently, the released organics were subjected to a bioassay for the generation of methane which conferred the potential application of fungal degradation as pretreatment. Additionally, fungal-mediated degradation was also prospected for extracting some other chemical entities like humic acids from brown coals with high huminite content especially from Thar, the largest lignite reserve of Pakistan.

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1. Introduction

Increased excavation and utilization of high rank coals have sparked interest in efficient utilization of massive resources of low rank and brown coals. With the increasing global energy demand, it is becoming indispensable to tap the colossal reserves of low rank coals. Transformation of coal into methane could help in providing energy for countries like Pakistan, which is experiencing an intense energy crisis in spite of a reserve of 185 billion tons of low rank coals [1]. Extraction of alternative fuels, particularly methane, is currently gaining interest due to technical constraints involved in exploitation and utilization of low rank coals. Furthermore, increasingly stringent environmental requirements may help make economical

the conversion of coal into alternative fuels like methane, which burns cleanly.

Naturally occurring coal bed methane (CBM) or coal seam gas, an unconventional gas, is emerging as an important energy source worldwide [2]. The biogenic origin of methane within the coal seams makes it plausible in theory to stimulate new methane generation in existing wells or in split process systems. On the other hand, coal is a recalcitrant geopolymer, and may not be readily degradable by microorganisms, especially methanogens. Mechanisms by which bacteria degrade coal to methanogenic substrates and finally into methane for biogenic generation are not completely understood, though in recent years there has been focus on developing some models for metabolic pathways involved in the biodegradation of coal to methane [3,4]. However, in all models of microbial production of methane from coal, the rate limiting steps involve the solubilization and degradation of coal to the

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substrates that can be utilized by methanogens for methane generation [5].

The solubilization of lignite (low rank coal) and subsequent breakdown into low-molecular weight aromatic and aliphatic compounds can be an indirect option for extracting some material capable of being fermented by anaerobic microorganisms [6]. This indirect step could be achieved by various methods including (i) extraction using organic solvents, (ii) enhanced bacterial decomposition of coal matrix, or (iii) fungal-mediated degradation. Addition of a solubilization step could serve as a pretreatment to enhance overall methane production. Fungal degradation of coal is especially interesting as it is well known that coals, particularly of low rank, contain some lignin-derived structures within the coal matrix which are susceptible to fungal attack [7]. *Phanerochaete chrysosporium*, *Penicillium* species and *Trichoderma atroviride* are some examples of fungi that are involved in solubilization of coal [8–10]. However, the role of fungi in the process of biogenic methane formation is unclear. Though in a recent report bacteria, archaea and fungi have been reported to be involved in methane release in abandoned coal mines where weathering of coal and timber is initiated by fungi and bacteria under a suboxic atmosphere [11]. But complete understanding of the mechanism for underground anaerobic carbon recycling and anaerobic degradation of coal is still needed

in order to develop effective methods for stimulating new biogenic methane production from the coal matrix.

The objective of this study was to investigate the fungal-mediated degradation of some representative lignite samples from Pakistani coal fields and to analyze those extracts for their potential to support subsequent methanogenesis based on previously reported models and using a bioassay to measure methanogenic potential of the fungal coal extract.

2. Materials and methods

2.1. Coal samples

2.1.1. Geological setting

Twelve low-rank coal samples from Sindh Province, Pakistan were subjected to fungal degradation in the laboratory. The samples were obtained from drill-core collected by the United States Geological Survey (USGS) and the Geological Survey of Pakistan (GSP) between 1986 and 1992. The samples used in this study were ground splits (<850 μm) that had been sealed in polyethylene and archived at USGS since shortly after drilling. Except for some secondary sulfate formation, much of which probably occurred shortly

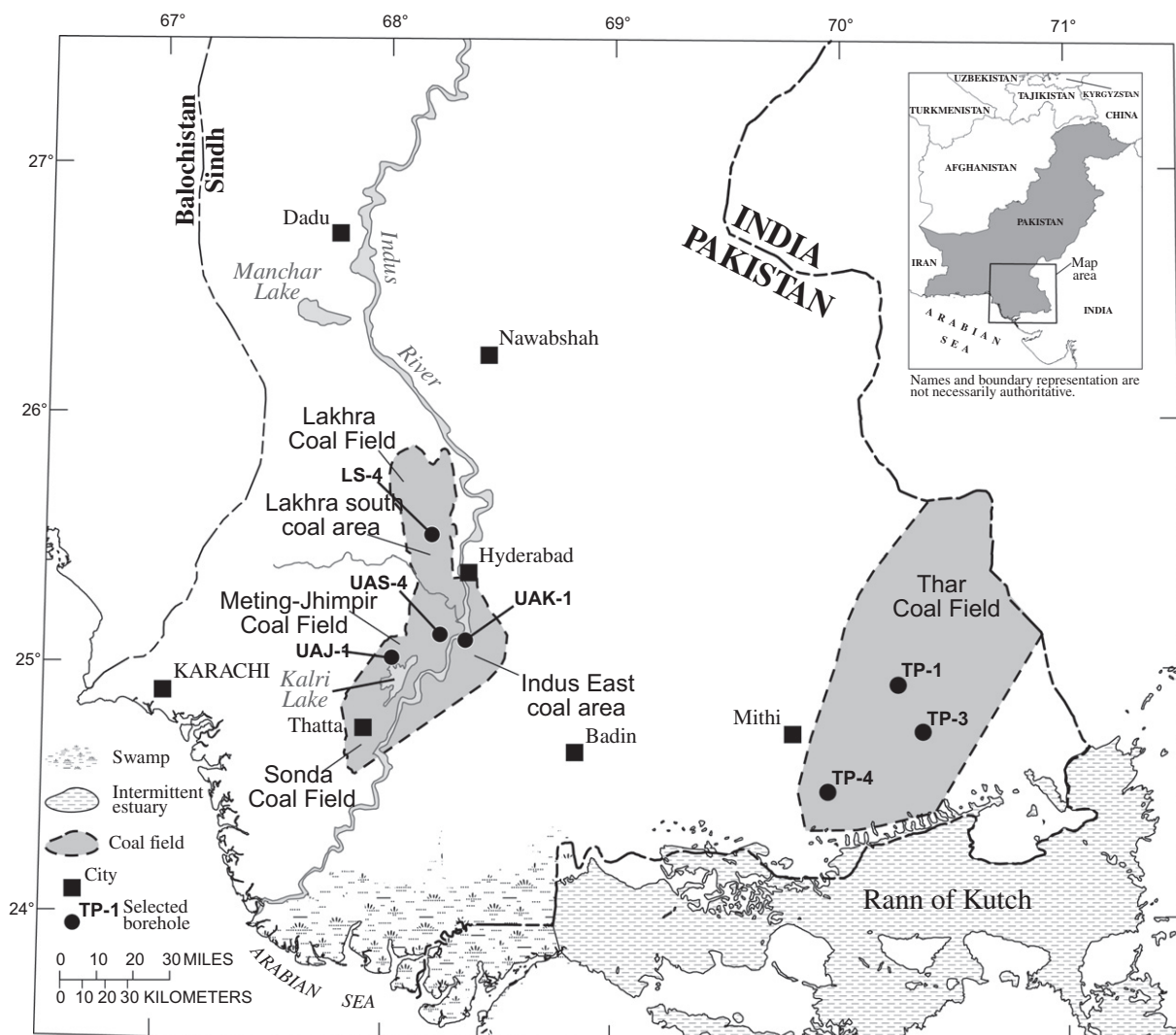


Fig. 1. Geographic setting and borehole locations for the samples used in this study. The sample numbers in Table 1 reflect the borehole number and sample bench (e.g. UAS-4-2E = borehole UAS-4, seam 2, bench E). Coal field boundaries are approximate.

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