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Hydrocarbon gas generation by biochemical process of moderately barophilic methanogens in Barapukuria coal mine gas reservoir & aquifer

Md. Sohel Ahmed [a,*], Mohammed Rahmatullah [b], Md. Anwar Arfien Khan [a]

[a] Bangladesh Council of Scientific & Industrial Research, Dr. Qudrat-i-Khuda Road, Dhanmondi, Dhaka 1205, Bangladesh
[b] Department of Biotechnology & Genetic Engineering, University of Development Alternative, Lalmatia, Dhaka 1207, Bangladesh

HIGHLIGHTS

- Physicochemical characteristics of Barapukuria coal.
- Proximate & ultimate analysis of Barapukuria coal.
- Biochemical coal gasification by moderately barophilic methanogens.

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ABSTRACT

The research reported the biogenesis of hydrocarbon gases form the bituminous coal by moderately barophilic methanogens of coal mine water adjacent to underground aquifer and gas reservoir site of Barapukuria coal basin. Physiochemical characteristics of the coal (with zero gas baseline) as carbon source (Seam *VI*, 390 m depth) for methanogens are determined. Parameters include inherent moisture content, volatile matter, ash content, calorific value, fixed carbon, α *factor*, *H/C ratio*, *CHNSO* elemental composition analysis, spectral assignments of ATR-FTIR, aromaticity factor f_a and degree of aromatic ring condensation $(R/C)_u$. Heavy, minors & light elements of calcined coal are also determined by X-ray fluorescence. Moderately barophilic methanogens surviving 5.61–6.45 MPa lithostatic pressure (taking Barapukuria coal average specific gravity 1.43) are identified by fluorescence at ultraviolet region (100–400 nm) of electromagnetic radiation and AQG-1 Methanometer. Bluish white fluorescence at UV is due to the redox coenzyme F_{350} in methanogens. Fluorescence at 350 nm excitation is bluish white. The methanogens only have the ability to produce gas in presence of coal which acts as an electrode surface to take up electron for hydrogenase and other enzymes for formation of hydrocarbon gases. They also have the coal biodegradability. The methanogens yielded methane, ethylene, ethane, propane, isobutane as detected by flame ionization detector of Bruker 450 gas chromatograph.

1. Introduction

The Barapukuria coal mining field is located near the Barapukuria village of Hamidpur union council under Parbatipur Thana of Dinajpur District of Bangladesh. The study area and its adjoining area are situated at the northern part of Bangladesh. The area located between latitudes 25°31′45″ and 25°33′5″ north and longitudes 88°57′48″ east to 88°58′53″ east, included in the survey of Bangladesh topographic sheet No. 78C/14. The coalfield contains coal bearing seams of 7 groups of eleven seams with total thickness 74.14 m. Seam VI is the main feasible bed for mining with thickness ranging from 29.4 to 41.00 meter and 36.41 meter on average, belonging to the regular and extra thick coal seam of the coal field. It stretches 4.9 kilometer northeast, with proved area approximately 5.8 square kilometer and has an unproved possible extension area of the south of approximately 1–1.5 square kilometer. The coal reserve of Barapukuria basin is 390 million metric ton. On the basis of fixed carbon content, calorific value and other chemical data, the Barapukuria coal can be classified as subbituminous to bituminous type. From the chemical data, it is observed that the moisture content is decreased downward with the increase of carbon content and reflectivity. This indicates the downward increase in rank [4].

Petrographic study of few coal samples from seam VI (336.20 m) of the drill hole GDH-38 (Geologic Depth Hole-38) was carried out by the Bangladesh Shell Petroleum 1n 1987. The

* Corresponding author.
E-mail address: sohel-ahmed@live.com (M.S. Ahmed).

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Nomenclature

Variables	Descriptors
VM	Volatile Matter
CV, *Q*	Calorific Value, $Q = m * C_p * \Delta t$; $m = Water\ weight$ $C_p = Heat\ Capacity\ of\ the\ cooling\ water$ $\Delta t = Temperature\ difference$
α *factor*	A variable of Goutel Formula, a factor that depends on the nature of volatile matter and its value decreases with rise in volatile matter
FC	Fixed Carbon
f_a	Aromaticity factor
$(R/C)_u$	Degree of Aromatic ring condensation, The number of the rings by atomic carbon by monomer
H/*C Ratio*	Hydrogen-Carbon Ratio
$\% R_0$	Vitrinite Reflectance
mL/min	Milliliter per minute
MPa	Megapascal, MPa is a metric pressure unit and equals to the 1000000 force of newton per square meter
nm	Nano micron
GHz	Gigahertz, GHz is a unit of measurement for alternating current (AC) or electromagnetic (EM) wave frequencies equal to 1,000,000,000 Hz
$\delta^{13}\ CH_4$	Isotopic signature of CH_4
E_0	Redox potential, a measure of tendency of a chemical species to acquire electrons and thereby be reduced. E_0 is measured in volts & mV
KW	Kilo Watt
mSv	Millisievert
cm^{-1}	Unit of Wavenumber
ΔG^0	Standard state free energy of reaction, $\Delta G^o = -RT \ln(keq)$, where, *keq* is equilibrium constant, *R* is the ideal gas constant units, *T* is the temperature; $\Delta G^o = -nFE_0$, where, *n* is the number of the electrons transferred in the reaction (from balanced reaction), *F* is the Faraday constant (96,500 C/mol) and E^0 is the potential difference
H_{al}/H	The fraction of total hydrogen present as aliphatic hydrogen
TDS	Total dissolved solid
DO	Dissolved Oxygen
EC	Electrical conductivity
Bragg's Formula	$n\lambda = 2dSin\theta$; λ = Wavelength of the diffracted X-rays, d = Lattice spacing of the crystal, θ = Crystal angle on diffraction, n = Order, 1 represents the measured element line, 2 or larger represents the higher order lines
C_{al}/H_{al}	The Hydrogen-carbon atomic ratio for aliphatic groups
Sv	Sievert, The SI unit of dose equivalent (the biological effect of ionizing radiation) equal to an effective dose of a joule of energy per kilogram of recipient mass, 1 *REM* = 0.01 Sv
KeV	Kiloelectron volt, KeV is equal to 10^3 eV, eV is a unit of energy equal to the energy acquired by an electron in being accelerated through a potential difference of 1 Volt; equal to 1.602×10^{19} *Joule*
Abs cm^{-1} mg cm^{-2}	The unit of concentration of infrared absorbing species $C(i)$ in the sample. The integral absorvity a_i (in absorbance units × wave number mg^{-1} cm^2) was determined which related the integrated area A_i (in absorbance units times wavenumber) to the concentration of absorbing species $C(i)$ in the sample ($mg\ cm^{-2}$) by the equation: $A_i = a_i C(i)$
μv	Micro-volt, 10^{-6} of a volt
MHz	10^6 Hz
STP	Standard Temperature Pressure
Kj/m^3	Kilo Joule per cubic meter
MJ/kg	Mega Joule per Kilogram
atm	Atmosphere (a unit of atmospheric pressure)
KPa	Kilopascal, KPa is a metric unit and equals to the 1000 force of newton per square meter
σ_{lith}	Lithostatic Pressure
ρ	Rock (Coal) Density
g	Gravitational Acceleration
z	Depth of coal seam
nmol/L	Nanomole per liter
MW	Mega Watt
mD	Millidarcy (unit of permeability)
α *particle*	A positively charged particle ejected spontaneously from the nuclei of some radioactive elements of higher atomic mass. It is identical to helium nucleus, having a mass number of 4 and an electrostatic charge of +2. (The magnitude of one electrostatic charge is equal to the charge on an electron or 1.602×10^{-19} Coulomb)
β *particle*	A charged particle emitted from a nucleus during radioactive decay, with a mass number equal to 1/1836 that of a proton
γ *ray*	High energy, short-wavelength electromagnetic radiation emitted from the nucleus
kcps	Kilo-counts per second, The X-ray intensity is expressed as the number of the X-ray photons that enter through the detector window in a unit time
μl	Micro liter
$\delta^{13}C, \Delta^{13}C$	An isotopic sign which is the measure of the ratio of stable isotopes $^{13}C/^{12}C$, reported as parts per thousands (*per mill* ‰)

result shows that Vitrinite reflectance 0.72, Vitrinite 86.0%, Liptinite (exinite) >5%, Inertinite 5%, Inorganic matters >3% [4].

Coal Bed Methane (CBM) has emerged as an important source of fossil energy. While the CBM is originally thought to be thermogenic origin, it is evident that microbial methanogenesis is significant in many formations. CBM is abundantly found in formations that have never been subject to conditions conducive to thermogenic methane formation [1].

Isotopic analysis of the gases from coal formations of varying maturity often indicates mixed signals that suggest both biological and abiotic origins of CBM [1]. Elevated paleo-temperature regimes may have constrained subsurface microbial activity in coal formations at some point in geological history, but the subsequent re-inoculation of shallow areas of North America, Australia and Asia has been hypothesized to allow microbial CBM formation to proceed [1].

$\delta^{13}C$ (an isotopic sign) is a measure of the ratio of the stable isotopes $13C : 12C$, reported as parts per thousands (*Per mill* ‰).

$$\Delta^{13}C = \left[(13_C/12_C)_{sample}/(13_C/12_C)_{standard} - 1\right] \times 1000\,‰$$

The abundance ratio of $13_C/12_C$ in reference standard Vienna Pee Dee Belemnite (VPDB) is 1.1237×10^{-2}.