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Assessing the environmental impact of bituminous coal from Barapukuria Coal Mine: thermogravimetric, microstructural, and morphological characterization for energy production implications

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Abstract
Coal, extensively used in many countries across various industries, particularly as a fuel in the energy sector, poses significant environmental challenges due to process-related implications and their complex characteristics. A notable obstacle arises from its heterogeneous and complex submicron–nano-molecular structure, often leading to operational issues that are challenging to predict. This research aims to comprehensively assess the environmental impact of bituminous coal sourced from the Barapukuria Coal Mine (NW Bangladesh). This study focuses on elucidating the intrinsic properties of coal, with specific attention to its thermal behavior, structural composition, and surface morphology, aiming to understand the implications for energy production. Advanced techniques, such as TGA/DTG, CHNS-O, XRD, FTIR, XRF, ICP-OES, XPS, SEM with EDX, and TEM, were employed. Rigorous experimentation and analysis provided valuable insights into combustion and pyrolysis processes, illuminating the release of environmentally hazardous pollutants and their negative consequences associated with the utilization of Barapukuria coal for energy generation. Thermogravimetric analysis indicates coal bond breakdown at 573–933 K, releasing gases and liquids during the breakdown stage, resulting in mass loss from moisture evaporation, protogenic gas release, and volatile matter loss. Despite being of the bituminous type, the coal exhibits a mean carbon concentration of 78.24% and a low sulfur content of 0.42%, signifying relative environmental friendliness compared to high-sulfur coals, which is crucial for preventing acid rain. The average higher heating value (31.04 ± 0.74 MJ kg^{-1}) and calorific value (30.20 ± 0.95 MJ kg^{-1}) indicate that the studied coals have high energy potential. This study also suggests that optimizing thermochemical conversion for power generation may enhance energy efficiency and mitigate potential environmental impacts. The research findings contribute to the scientific understanding of coal thermal properties, serving as a foundation for informed decision-making in energy production strategies that prioritize both efficiency and environmental sustainability.

Keywords Barapukuria bituminous coal · Thermo-gravimetric analysis · Energy potentiality · Sustainability

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