

## Abstract

This research focuses on the application of advanced dry beneficiation and froth flotation techniques to overcome the challenges associated with high-ash Indian coals. A batch-scale dry beneficiation process was implemented using a Dense Medium Fluidized Bed (DMFB) separator. Coal samples were sourced from Mahanadi Coalfields (Samaleswari, Garjanbhahal, and Bhubaneswari OCPs) in Odisha and Jharia Coalfield (Ena, Kuya, and Bastacolla OCPs) in Dhanbad. Comprehensive characterization, including proximate and ultimate analysis, washability testing, gross calorific value (GCV), petrographic analysis, XRD, XRF, LTGK, and FSI, was conducted to understand the coal properties. Key process parameters, such as air flow rate, bed height, and medium particle size, were optimized for effective coal upgrading. 2D simulation studies using Ansys Fluent software analyzed gas velocity, particle interactions, and void fractions, revealing that a superficial gas velocity of 1.8 to 2.0 times the minimum fluidization velocity and a medium particle size range of  $-150+106\text{ }\mu\text{m}$  were most favorable for efficient dry beneficiation. Experimental results showed that for non-coking coal, coarser fractions ( $-50+6\text{ mm}$ ) from Garjanbhahal and Bhubaneswari provided higher clean coal yields (60% and 58%) and combustible recoveries (70% and 69%), while Samaleswari's  $-25+6\text{ mm}$  fraction achieved a clean coal yield of 48.5% with 31% ash and 57% recovery. Garjanbhahal samples exhibited the highest organic efficiency (93.05%) and the most significant GCV enhancement (from 3906 to 4790 kcal/kg), with an overall ash reduction of 7–9 percentage points. For coking coals, dry deshaling reduced ash content significantly (e.g., Ena coal from 35.3% to 29.6% with a 75.4% yield). Subsequent froth flotation, using NALCO synthetic reagents, further reduced ash levels to 17.5% with an 85% yield. Kuya coal displayed excellent organic efficiency (88%) with ash content reduced from 38.97% to 30.73% during dry processing. Bastacolla coal also showed improved ash rejection. Using Response Surface Methodology (RSM), optimal flotation conditions (0.200 kg/T frother, 0.885 kg/T collector) produced clean coal with 18% ash content. The integrated approach of dry beneficiation and froth flotation demonstrates significant potential for upgrading high-ash coals, achieving improved coal quality while addressing the challenges of limited water availability in India.

**Keywords:** *High Ash Indian Coals, Dense Medium Fluidized Bed, Dry Coal Beneficiation, Froth Flotation Optimization, Ash Reduction and Washability*