Goldschmidt 2024 Abstract
https://doi.org/10.46247/gold2024.22530

Surface modification of a solid carbon by-product generated from methane pyrolysis for environmental applications

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Methane pyrolysis, a prevalent method for producing hydrogen, yields substantial amounts of solid carbonaceous byproduct (SCB) with physiochemical properties similar to commercially available carbon black. With hydrogen emerging as a promising clean energy source to mitigate CO_2 emissions and climate change, the utilization of methane pyrolysis is projected to grow. This study investigates the adsorption of cadmium, Cd(II), by commercial carbon black modified using several low-cost modification approaches that could be scaled for commercial application. Diverse chemical modification techniques, including HNO_3, NaOH, and air oxidation treatments, were employed to functionalize the surface of the carbon black, making it more reactive towards cadmium. All acid, base, and air oxidation modifications caused morphological changes in the pure carbon black, as evidenced by surface area measurements and scanning electron microscopy (SEM) analysis. CHNS/O elemental analysis confirmed the introduction of oxygen on the modified carbon black surfaces, with the highest amount on NaOH-modified and the lowest on the air-oxidized carbon black. Following modification, the point of zero charge (PZC) of the carbon blacks was more acidic than the parent carbon black, further supporting the introduction of oxygen-bearing functional groups on carbon black surfaces, resulting in heightened cadmium removal. The NaOH-modified material showed the best adsorption performance for the removal of Cd from a synthetic aqueous solution, removing approximately 85% Cd(II) from a 1 g/L solution, while the acidified and air-oxidized carbon blacks showed adsorption extents of almost 40% and 10%, respectively. The adsorption performance was found to be strongly dependent on the solution pH, with a maximum difference between the modified and unmodified carbons observed at pH of 7.0, above which Cd precipitation dominates removal from solution. These findings offer valuable insights into potential alternative uses of SCB produced via methane pyrolysis for water treatment applications.