

Comparative Regeneration of Spent Activated Carbon via Chemical (HCl, NaOH) and Microwave-Assisted Methods

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Structured Abstract

Background: The disposal of spent activated carbon (SAC) from water purification systems poses significant environmental and economic challenges. Traditional disposal methods contribute to waste accumulation and resource inefficiency, necessitating sustainable regeneration techniques. This study systematically evaluates the regeneration of SAC using hydrochloric acid (HCl), sodium hydroxide (NaOH), and microwave irradiation, aiming to restore its adsorption capacity and support circular economy strategies in water treatment industries.

Methods: SAC was regenerated through chemical and microwave-assisted methods. For chemical regeneration, SAC was treated with HCl (0.5–5%) and NaOH (0.5–5%) at varying contact times (10–30 min). Microwave regeneration employed power levels (300–800 W) and durations (10–20 min). Regeneration efficiency was assessed using iodine value (IV) tests, scanning electron microscopy (SEM) for morphological analysis, and Fourier-transform infrared spectroscopy (FTIR) for surface chemistry characterization.

Results: The results demonstrated method-specific efficiencies. HCl regeneration (5%, 30 min) restored the IV to 467.7 mg/g, effectively clearing inorganic contaminants and recovering pore structure. NaOH regeneration (5%, 30 min) achieved near-virgin-carbon performance (IV: 572.5 mg/g) against organic contaminants, though diminishing returns were observed beyond 15 min. Microwave treatment (600 W, 15 min) achieved broad applicability (80–95% efficiency) to mixed contaminants, with minimal burn-off (<10%) and rapid restoration of porosity. All methods significantly reactivated SAC adsorption capacity, with chemical regeneration offering targeted, low-energy solutions and microwave providing rapid, versatile thermal desorption.

Conclusion: The study highlights the efficacy of HCl, NaOH, and microwave-assisted methods in regenerating SAC, with optimized parameters (5% HCl/30 min, 5% NaOH/15–30 min, 600 W MW/15 min) balancing efficacy and operational cost. These findings support sustainable SAC reuse, reducing environmental impact and promoting resource efficiency. Future research should explore hybrid approaches, multi-cycle stability, eco-friendly chemical alternatives, and pilot-scale validation to advance circular economy strategies in water treatment.

Keywords: Spent activated carbon, regeneration, chemical treatment, microwave irradiation, adsorption capacity

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