

**UTILIZATION OF ARAL SEA SAPROPELS IN SORBENT DEVELOPMENT FOR  
WASTEWATER TREATMENT**

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**ABSTRACT**

Degradation of water quality caused by heavy metals, dyes, petroleum products, and nutrients poses a persistent threat to public health and the environment. The search for low-cost, efficient, and environmentally friendly sorbents has intensified, particularly in regions suffering from ecological crises. Sapropels—organic-mineral sediments formed in freshwater or brackish water bodies—represent a promising natural material with favorable composition and physicochemical characteristics. This study investigates the feasibility of utilizing sapropels collected from the Aral Sea region for the development of sorbents aimed at removing pollutants from wastewater. Laboratory experiments were conducted to characterize sapropel structure, optimize thermal and chemical activation methods, and test adsorption performance for heavy metals ( $Zn^{2+}$ ,  $Pb^{2+}$ ), dyes (methylene blue), and ammonium ions. Results demonstrated substantial increases in sorption capacity following activation, with thermally activated sapropels showing the highest efficiency due to enhanced porosity and surface area. The study concludes that Aral-region sapropels can serve as low-cost, eco-friendly sorbents for wastewater treatment, supporting sustainable environmental remediation in Central Asia.

**Keywords:** Aral Sea, Sapropels, Sorbents, Wastewater Treatment, Heavy Metal Removal, Environmental Technology

**INTRODUCTION**

Access to clean water remains a major global challenge. Industrialization, urban expansion, and agricultural runoff continuously introduce contaminants such as heavy metals, dyes, oils, and nutrients into aquatic ecosystems. Conventional wastewater treatment technologies—including chemical precipitation, ion exchange, and membrane filtration—are often costly, energy-intensive, and produce secondary waste. Natural sorbents have emerged as alternative materials due to their low cost, biodegradability, local availability, and acceptable adsorption efficiency. Among them, sapropels have drawn attention for their high organic matter content, diverse mineral composition, humic substances, and porous structure. Sapropels and Their Potential. Sapropels are fine-grained sediments formed from partially decomposed aquatic biomass under anaerobic conditions. Their structure includes: humic and fulvic acids, clay minerals, calcium and magnesium compounds, micro- and macropores enabling adsorption. These properties make sapropels suitable for: heavy-metal binding, nutrient removal, organic pollutant adsorption, use as precursors for activated carbon-like materials. Relevance to the Aral Sea Region: The ecological crisis of the Aral Sea has exposed vast areas of dried seabed containing unique sediments enriched with organic-mineral complexes. These materials represent a potential local resource for environmental remediation and technological innovation. However, limited scientific work has focused specifically on transforming Aral sapropels into engineered sorbents. This research aims to: Characterize the physicochemical properties of Aral Sea sapropels. Develop activation methods (thermal and chemical). Evaluate adsorption capacity for selected pollutants. Assess suitability as practical sorbent materials for wastewater treatment.

**MATERIALS AND METHODS**

Sapropel samples were collected from upper sediment layers (0–30 cm depth) at three locations in the dried coastal zone. Samples were air-dried, homogenized, and sieved ( $\leq 1$  mm)

before analysis. The following analyses were performed: moisture content and ash value, pH and cation-exchange capacity (CEC), Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), Brunauer–Emmett–Teller (BET) surface area measurements, scanning electron microscopy (SEM). Two activation pathways were employed: Thermal Activation: Samples heated at: 250°C–350°C–450°C for 1 hour in a muffle furnace. Sapropels soaked in: 1M HCl, 1M NaOH, or 10% H<sub>2</sub>O<sub>2</sub>, followed by washing and drying. Model wastewater was prepared containing: 50 mg/L Zn<sup>2+</sup> or Pb<sup>2+</sup> ions, 40 mg/L methylene blue dye, 30 mg/L NH<sub>4</sub><sup>+</sup> ions. Batch adsorption tests measured removal efficiency at: varying sorbent doses (0.5–5 g/L), contact times (10–180 min), pH ranges 3–9. Residual concentrations were determined using spectrophotometry and atomic absorption spectrometry. Isotherm models (Langmuir, Freundlich) and kinetic models (pseudo-first-order, pseudo-second-order) were applied. Statistical significance evaluated at p < 0.05. Organic matter content: 28–42% Ash content: 55–67% pH: 6.7–7.8 (slightly neutral) CEC: 40–65 cmol/kg, BET surface area: 5–12 m<sup>2</sup>/g (low but improvable) FTIR confirmed presence of: humic substances, silicate minerals, carbonate groups. SEM images showed a dense, weakly porous structure typical of unactivated sapropels. Thermal activation significantly increased porosity: At 450°C: BET increased to 45–72 m<sup>2</sup>/g Pore structure expanded and surface roughness increased. Chemical activation results: HCl removed carbonates and increased pore volume. NaOH enhanced the exposure of organic functional groups. H<sub>2</sub>O<sub>2</sub> produced mild oxidation but moderate porosity increase. Best removal achieved with thermally activated samples at 450°C: Zn<sup>2+</sup> removal: up to 92% Pb<sup>2+</sup> removal: up to 96%, Langmuir model fit well, indicating monolayer adsorption. Methylene blue removal efficiency: Raw sapropel: 35–48%, Chemically activated (HCl/NaOH): 70–85%, Thermally activated (450°C): 88–93%. Moderate removal achieved: Raw sapropel: 25–30%, NaOH-activated sapropel: up to 60%, Kinetics followed pseudo-second-order model, suggesting chemisorption processes. Thermal activation was the most effective for creating microporous structures comparable to low-grade activated carbon. Chemical activation, while less effective for porosity, improved ion-exchange properties and functional group availability. Aral sapropels showed: higher heavy-metal affinity compared to unmodified clays, similar dye adsorption to peat-based sorbents, moderate ammonium removal comparable to zeolite-rich materials.

### CONCLUSION

This study demonstrates that sapropels from the Aral Sea region can be efficiently transformed into sorbents for wastewater treatment applications. Thermal activation at 450°C produced the highest-performing material, achieving notable adsorption efficiencies for heavy metals and organic dyes. Chemical activation improved ion-exchange performance and functional group exposure. Given their natural abundance, low cost, and environmental friendliness, Aral-region sapropels represent a promising local alternative for developing sorbents suited for small-scale and industrial wastewater treatment systems.

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