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Turning Waste into Value: Integrated Utilization of Molybdenum Tailings for Synthesizing High-Performance Adsorbents to Treat Nitrogen and Phosphorus Pollution

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Long-term impoundment of molybdenum tailings (MT) presents potential risks of heavy metal leaching and geological hazards, such as landslides and slope instability; however, their high silicon and aluminum contents offer considerable opportunities for material valorization. This study first assessed the environmental characteristics of MT, confirming high Si and Al levels and total heavy metal concentrations below national risk screening thresholds, demonstrating their suitability as a low-cost secondary resource.

Pretreated MT were subsequently utilized as a silicoaluminate source to synthesize FAU-type zeolite (MTZ-3) via a hydrothermal method. The synthesized MTZ-3 exhibited rapid and efficient ammonia adsorption, reaching equilibrium within 30 minutes and achieving a maximum adsorption capacity of 17.04 mg/g. Adsorption was primarily governed by an ion-exchange mechanism.

Simultaneously, the leachate generated during tailing pretreatment was employed to prepare calcium–iron metal oxides (CaFeMOs). The CaFeMOs showed a high phosphate adsorption capacity of 90.04 mg/g and were further applied to stabilize acidic phosphogypsum. At a 2% dosage, CaFeMOs effectively neutralized pH and achieved a phosphorus stabilization efficiency exceeding 96%.

Overall, this study establishes a synergistic, full-process valorization pathway integrating solid tailings and associated leachate. The proposed approach mitigates environmental risks linked to tailings storage while producing functional materials for nitrogen and phosphorus pollution control. These findings provide a practical and sustainable technical strategy for tailing resource utilization and co-contaminant remediation.