Beneficial Use of Contaminated Sediments: Focused Review of Treatment Technologies

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Rising costs and decreasing disposal options are driving innovation in treatment technologies for contaminated sediments.

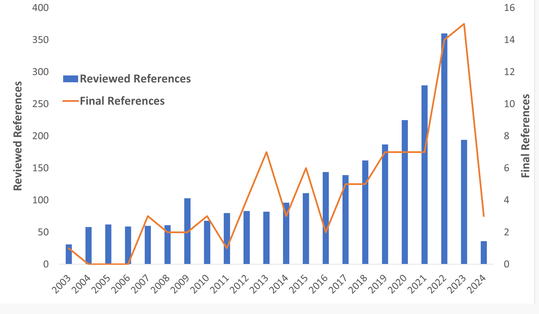
The management of contaminated dredged materials faces a critical challenge: diminishing disposal options and rising costs necessitate exploration of alternatives to disposal, such as beneficial use.

This review evaluates *ex situ* treatment technologies and factors influencing success for treating contaminated sediments for subsequent beneficial use.

Comprehensive literature review identifies key advances and gaps in treatment technologies.

Our research encompassed both traditional and AI-powered research tools to analyze more than 2,600 sources from the past 20 years. Ninety-seven references met the final criteria for inclusion, with emphasis on publications from 2018–2024. This approach enabled comprehensive assessment of:

- Recent technological advances
- Implementation challenges
- Success factors
- Knowledge gaps



Treatment Technologies Overview

	Recent Advances	Research Needs	Factors Influencing Success
Immobilization (S/S) (Solidification and Stabilization)	• Using pretreatment methods (washing, thermal) that reduce contaminant load prior to S/S processing • Making low-carbon cementitious materials with reduced metal leaching through aggregate modification • Enhancing hydrocarbon contaminant stability in S/S products using biochar, activated carbon, and iron-based additives	• Full-scale S/S application demonstrations with stability verification • Climate condition effects on binder performance and stability • Optimization of sequestration treatments for contaminant binding	• Heterogeneity of the dredged material • Stability of final product may require prior segregation of materials and frequent performance testing • Feasability of ecosystem restoration applications with lower strength requirements • Risks related to leachability of immobilized contaminants
Chemical/Physical Extraction	• Increasing removal efficiencies of metals and organic contaminants with surfactants • Enhancing electrokinetic remediation (EKR) efficiency through strong acids, bioremediation integration, or increased voltage, despite higher energy demands • Achieving promising results from laboratory-scale ionic liquids, flotation, microwave- or ultrasonic-assisted chemical extractions	• Optimization of sediment washing considering organic fraction influence and particle size range effects on solid-to-liquid ratio and treatment duration • Evidence of successful, cost-effective EKR applications beyond laboratory/pilot scale • Research on chemical extraction optimization at full scale considering sediment heterogeneity	• Energy-intensive processes with high costs • Structural properties of treated materials limit end use • Processes not extensively applied at large scales
Bioremediation	• Enhancing bioleaching/bioslurry treatments with sequestration integration for metals • Using dual-action phyto-microbial remediation for metals and organic contaminants • Improving efficiency through biological process combination	• Field-scale effectiveness validation • Microbial diversity optimization for field conditions • Treatment acceleration via biochar and compost amendments	• Chemical mobility risks • Large land area and long duration requirements • Structural properties of treated materials limit end use

Key Considerations

Proposed use
Cost
Safety
Removal efficiency
Duration/schedule
Environmental impact
Regulatory acceptance
Proven performance

Potential Applications

Future Direction

We recommend the development of a platform for sharing information about treatment technologies of contaminated sediments and beneficial use. This tool can help optimize decisions and simultaneously manage costs, remediation time, and future environmental risks. Key elements of such a platform could include:

- **A data repository or clearinghouse** for data compilation on treatment technologies and beneficial use applications
- **Broad access** to the clearinghouse to allow for easy data entry by project proponents
- **Data quality rules** to ensure consistency among data entries and to allow meaningful comparisons among projects
- **Opportunities to partner** with permitting agencies to capture project details
- **Knowledge and/or data sharing** through partnerships with practitioners implementing current projects.

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