Sustainable Materials and Technology

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Quantum Catalysis Reactions for Sustainability

Catalytic Reaction for Sustainability

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Quantum Catalysis for the Removal and Recovery of Metal Ions in Textile Effluents

Sana Nisar, Naseem Ahmad, Arshad Iqbal, and Nafees Ahmad

Abstract Quantum catalysis has emerged as an adapting approach for the removal and recovery of metal ions from textile effluents, addressing both environmental pollution and resource recovery challenges. The excellent properties of quantum nanomaterial, include high surface area, quantum confinement effects, and tunable electronic structures. Quantum catalysts exhibit exceptional efficiency in adsorbing, reducing, and recovering toxic metal ions like chromium, cadmium, lead and arsenic from wastewater. Advanced quantum catalytic systems, including quantum dots, single-atom catalysts, and hybrid nanocomposites, facilitate the degradation of a wide range of contaminants and the simultaneous recovery of valuable metal ions through redox reactions and photocatalytic mechanisms. This chapter highlights the innovative potential of quantum catalysis in the removal of metal ions from textile effluent, emphasizing its dual role in environmental remediation and sustainable resource utilization. By integrating cutting-edge nanotechnology with wastewater management, quantum catalysis offers a promising pathway to mitigate the environmental impact of the textile industry while promoting circular economy principles.

Keywords Quantum catalysis · Heavy metals · Quantum confinement · Electronic structure · Environmental remediation

1 Introduction

The rapid urbanization and industrialization has significantly increased the discharge of wastewater containing micropollutants into freshwater systems. These micropollutants including heavy metals, organic dyes, fertilizers and pharmaceutical and personal care products residues not only deplete freshwater resources but also pose serious threat to human health and aquatic species [1]. Among them, heavy metals such as chromium (Cr), lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) are of particular concern due to their high toxicity, persistence, and non-biodegradable

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with membrane and electrochemical systems may improve their application in the removal of heavy metals. Future research should focus on scalable synthesis, long-term stability, and regeneration strategies to enable real-world application. Additionally, understanding the mechanistic pathways of quantum catalyzed reactions at the atomic level using advanced spectroscopic and computational techniques is crucial. Overall, quantum catalysis holds great promise as a next-generation solution for achieving circular economy goals in the textile industry through effective effluent treatment and resource recovery.

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References

1. Rathi BS, Kumar PS, Vo DVN (2021) Critical review on hazardous pollutants in water environment: occurrence, monitoring, fate, removal technologies and risk assessment. Sci Total Environ 797:149134
2. Sarkar B, Sharma U, Adhikari K, Lahiri SK, Baltrėnaitė E, Baltrėnas P, Dutta S (2021) Application of artificial neural network and particle swarm optimization for modelling and optimization of biosorption of lead (II) and nickel (II) from wastewater using dead cyanobacterial biomass. J Indian Chem Soc 98(3):100039
3. Mishra S, Bharagava RN, More N, Yadav A, Zainith S, Mani S, Chowdhary P (2018) Heavy metal contamination: an alarming threat to environment and human health. In: Environmental biotechnology: for sustainable future. Springer, Singapore, pp 103–125
4. Velusamy S, Roy A, Sundaram S, Kumar Mallick T (2021) A review on heavy metal ions and containing dyes removal through graphene oxide-based adsorption strategies for textile wastewater treatment. Chem Rec 21(7):1570–1610
5. Saleh TA, Mustaqeem M, Khaled M (2022) Water treatment technologies in removing heavy metal ions from wastewater: a review. Environ Nanotechnol Monitor Manag 17:100617
6. Schellenberg T, Subramanian V, Ganeshan G, Tompkins D, Pradeep R (2020) Wastewater discharge standards in the evolving context of urban sustainability–The case of India. Front Environ Sci 8:30
7. Peng H, Guo J (2020) Removal of chromium from wastewater by membrane filtration, chemical precipitation, ion exchange, adsorption electrocoagulation, electrochemical reduction, electrodialysis, electrodeionization, photocatalysis and nanotechnology: a review. Environ Chem Lett 18(6):2055–2068
8. Qasem NA, Mohammed RH, Lawal DU (2021) Removal of heavy metal ions from wastewater: a comprehensive and critical review. NPJ Clean Water 4(1):1–15
9. Fu F, Wang Q (2011) Removal of heavy metal ions from wastewaters: a review. J Environ Manag 92(3):407–418
10. Hui KC, Ang WL, Sambudi NS (2021) Nitrogen and bismuth-doped rice husk-derived carbon quantum dots for dye degradation and heavy metal removal. J Photochem Photobiol A 418:113411
11. Bhattacharjee T, Konwar A, Boruah JS, Chowdhury D, Majumdar G (2023) A sustainable approach for heavy metal remediation from water using carbon dot based composites: a review. J Hazard Mater Adv 10:100295
12. Jha R, Pal R, Chakraborty D, Chattaraj PK (2023) Principles of catalysis. Metal phosphates and phosphonates: fundamental to advanced emerging applications. Springer International Publishing, Cham, pp 95–113