RECENT DEVELOPMENTS IN THE REMOVAL OF HEAVY METALS IN WATER AND WASTEWATER

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Introduction

Heavy metals, ubiquitous in industrial effluents and natural water sources, pose significant environmental and health risks. Recent years have witnessed remarkable advancements in the field of heavy metal removal from water and wastewater. This poster aims to highlight the latest developments, innovative approaches, and emerging trends in the removal of heavy metals, offering insights into the forefront of research and applications in this critical area.

Membrane Filtration

Membrane filtration techniques can achieve high removal efficiencies, often exceeding 90% for various heavy metals including chromium, cadmium, and arsenic. Requires pressure difference

Ultrafiltration

Modified UF membrane either polymer enhanced or micellar enhanced. Removed up to 99.6% Mn, 97% of Cd and 99.5% of Ni

Nanofiltration

The most effective pressure driven methodology. removed 98% of Mg, 95% of Cd, >98% of Cd and 93% of Pb.

Reverse Osmosis

Mostly used in desalination processes. Removal of >99% of Cu, 99.03% of Ni, 99.37% of Cr and ~100% of Pb.

Hongrui Xiang et al. Recent advances in membrane filtration for heavy metal removal from wastewater: A mini review, 2022, https://doi.org/10.1016/j.jwpe.2022.103023

Adsorption (Classic Methods)

Activated Carbon: Activated carbon is a highly porous material with a large surface area, which makes it effective for adsorbing heavy metals from wastewater.

Ion Exchange: Ion exchange involves the exchange of ions between a solid phase and a liquid phase. In the context of heavy metal removal, ion exchange resins are commonly used to selectively remove metal ions from wastewater by exchanging them with other ions present in the resin.

Chelation: Chelating agents are chemical compounds that can form complexes with heavy metal ions, thereby reducing their concentration in wastewater. These complexes are often more stable and less toxic than the free metal ions, facilitating their removal from the wastewater.

Biological treatment: Divided into Biosorption (Organisms, through metabolic processes or passive binding mechanisms, accumulate heavy metals from wastewater in their bodies) and Bioremediation (Conversion of soluble metal ions into insoluble complexes that precipitate)

Activated Carbon

Removal of lead 93-96% from water

Bazana S.L. et al., Modified activated carbon with silver-copper mixed oxides nanoparticles for removal of heavy metals from water, 2019, International Journal of Environmental Science and Technology, 10.1007/s13762-019-02260-3

Ion Exchange

Removal of 48% of cobalt from mining wastewater

Abeywickrama J. et al. Selective extraction of cobalt and copper from chilean mine water by ion exchange resin, 2020, Mining Science and Technology (Russian Federation), 10.17073/2500-0632-2020-1-25-29

Chelation

Stabilization of 93.0% of Cadmium and 99.7% of Copper

Miao, Chen et al, Mechanism analysis of the immobilization of heavy metal ions with the water-soluble polymer: The influence of resin structure and the further adsorption of chelate, 2022, Journal of Environmental Management, 10.1016/j.jenvman.2021.114087

Dangers of heavy metals

Toxicity

Prolonged exposure to these metals through contaminated water can lead to various health issues including neurological damage, kidney and liver damage, respiratory problems, cardiovascular diseases, and certain types of cancer.

Reproductive health

Exposure to certain metals like lead and cadmium has been linked to infertility, miscarriages, and birth defects. Maternal exposure to lead and mercury has been linked to congenital abnormalities such as neural tube defects, heart defects, and limb deformities in newborns.

Developmental and Neurological effects

Heavy metal exposure, particularly in children and developing fetuses, can have severe developmental and neurological effects. Lead exposure, for example, is associated with developmental delays, learning disabilities, behavioral problems, and decreased IQ.

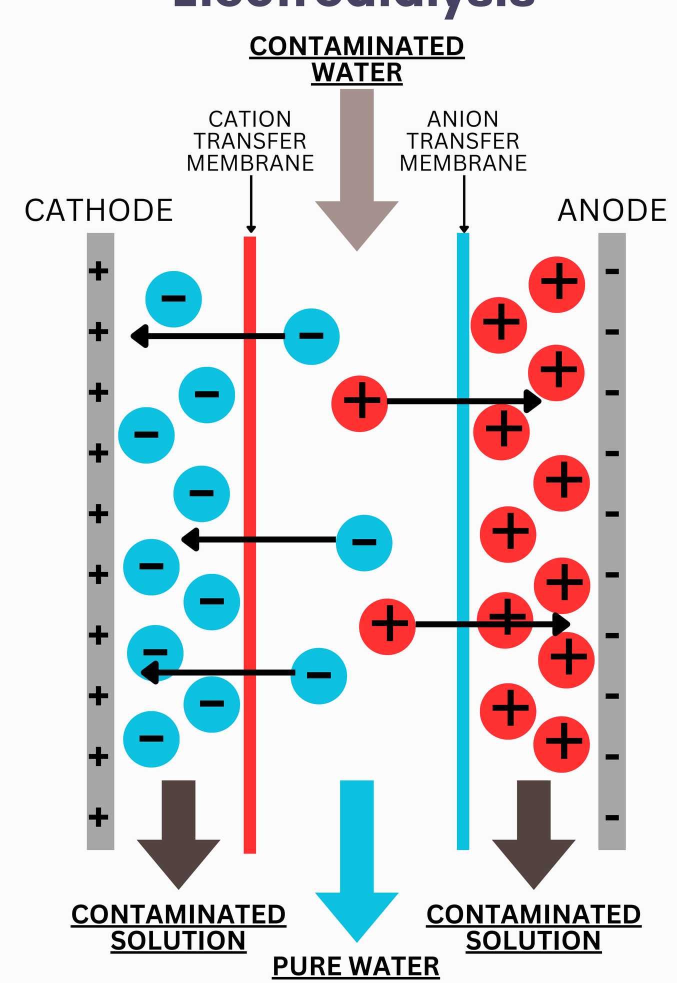
Electrochemical Methods

Electrodialysis: Hybrid technique with membrane filtration. Chemical free. High recovery rates of clean water.

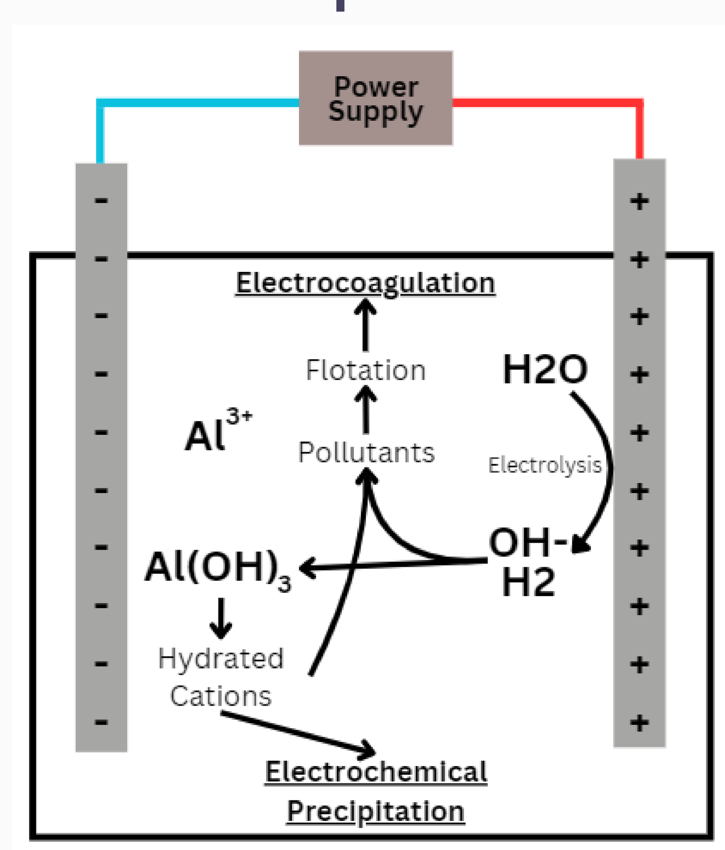
Electrocoagulation: Generation of coagulating agents like metal hydroxide flocs via electric current. Separation through sedimentation or filtration

Electrochemical Precipitation: Current induced precipitation of heavy metals as insoluble ions. These are then separated via filtration or sedimentation.

Electrodialysis



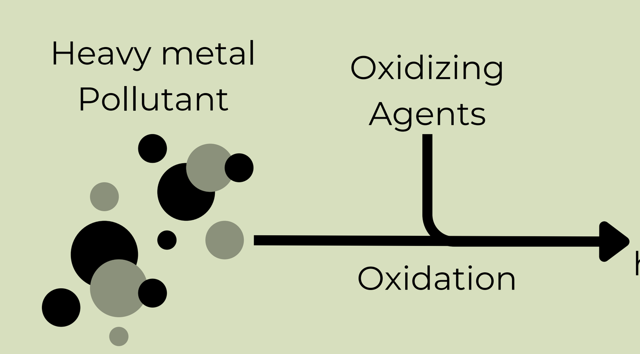
Electrocoagulation and Electrochemical Precipitation



Hybrid systems and Novelties

Advanced Oxidation Processes (AOPs)

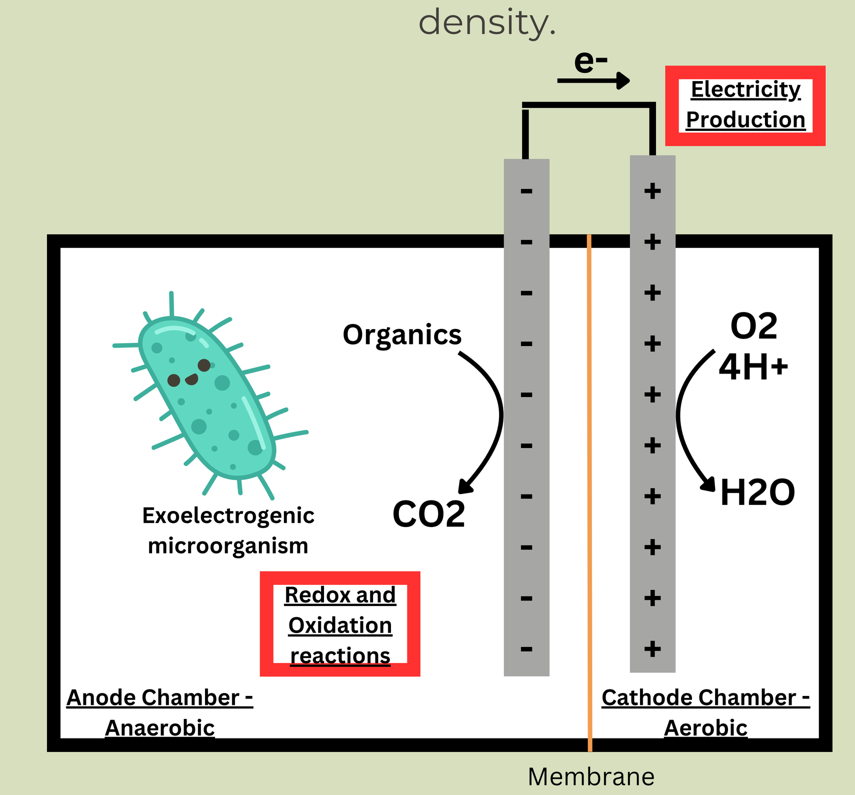
Use of powerful oxidizing agents (ozone, hydrogen peroxide, or UV light) to degrade organic contaminants and oxidize heavy metal ions in wastewater.



Bioelectrochemical Systems - Microbial Fuel Cells (MFCs)

MFCs are devices that use exoelectrogenic microorganisms as biocatalysts and then convert chemical energy to electrical energy directly via substrate oxidation

- removal of 98.3% of Cu(II) in 28 hours with an energy output of 10.2 W/m3;
- removal of Cr(VI) with a single chamber MFC reached 100% of removal with 1221.91 mW/m2 power density;
- removal of 99.54% of Hg(II) with 318.7 mW/m2 power density;
- Removal of 99.88% of Au(III) with 6.58 W/m2 power density.



Fang et al. The Potential of Microbial Fuel Cells for Remediation of Heavy Metals from Soil and Water—Review of Application, Microorganisms, 2019, 10.3390/microorganisms7120697

Designing an effective heavy metal removal system...

Scalability: Application to various scales of operation, from small applications to wastewater treatment plants.

Cost-effectiveness: Minimizing material expenses, energy consumption, labor and maintenance.

Environmental sustainability: Prioritizing low energy consumption, waste generation, renewable energies, green chemicals and resource recovery.

Conclusion

From innovative adsorption materials to cutting-edge membrane technologies, these developments offer promising solutions for effectively removing heavy metals and safeguarding both human health and the environment. it is important that this research gets translated into practice as we move forward with widespread implementation to ensure access to clean and safe water for all. By fostering collaboration between researchers, policymakers, and stakeholders, we can work towards a sustainable future where heavy metal pollution is mitigated, and water resources are preserved for generations to come.

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NuFoG Nutrition Food Group Universida de Vigo

CIMO Centro de Investigação de Montanha

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