How to Remove Excess Copper from Water

Techniques and Strategies

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INTRODUCTION

- Elevated copper levels in water bodies can arise from industrial contamination, natural geological processes, or the use of copper-based algaecides.
- High levels of copper can pose risks, making it essential to minimise copper concentrations in accordance with the guideline values in the water[1].
- This article explores various scientifically-backed techniques for removing copper, focusing on methods such as the use of **limestone**, **chemical precipitation**, **phytoremediation**, **reverse osmosis**, and **activated carbon filters**.
- Additionally, we will compare these techniques to help determine the most suitable approach depending on the context.

TECHNIQUES FOR REMOVING COPPER FROM WATER

LIMESTONE ADDITION (CALCIUM CARBONATE PRECIPITATION)

Mechanism	▪ Limestone (calcium carbonate) increases the pH of water, promoting the precipitation of copper as insoluble compounds, primarily copper carbonate ($CuCO_3$). ▪ This precipitate can be removed through natural processes[2].
Application	▪ Copper ions can adsorb onto the surface of limestone[2] ▪ As calcium carbonate dissolves, it can co-precipitate copper along with calcium and carbonate ions[2]. ▪ This method is widely used in industrial wastewater treatment, especially where copper concentrations are high.
Pros and Cons	▪ Limestone is an inexpensive and readily available material compared to other treatment options. ▪ The process is most effective in acidic to neutral pH ranges, as it may temporarily raise the waters pH.

CHEMICAL PRECIPITATION

[1] Liu, Y., Wang, H., Cui, Y., & Chen, N. (2023). Removal of Copper Ions from Wastewater: A Review. *International journal of environmental research and public health*, *20*(5), 3885. https://doi.org/10.3390/ijerph20053885

[2] Aziz HA, Othman N, Yusuff MS, Basri DR, Ashaari FA, Adlan MN, Othman F, Johari M, Perwira M. Removal of copper from water using limestone filtration technique. Determination of mechanism of removal. Environ Int. 2001 May;26(5-6):395-9. doi: 10.1016/s0160-4120(01)00018-6. PMID: 11392757.

Mechanism	▪ Reagents such as sodium sulphide (Na_2S) or sodium hydroxide (NaOH) are added to water, causing copper to precipitate as insoluble compounds like copper sulphide (CuS) or copper hydroxide ($Cu(OH)_2$)[1].
Application	▪ This method is widely used in industrial wastewater treatment, especially where copper concentrations are high.
Pros and Cons	▪ Chemical precipitation is effective and can handle large volumes of water. ▪ However, it produces sludge that may need to be properly managed to prevent build-up of organic material.

PHYTOREMEDIATION

Mechanism	▪ Certain plants, known as hyper accumulators, absorb and accumulate copper from water or soils[3]. ▪ The plants can then be harvested and disposed of safely.
Application	▪ Phytoremediation is suitable for treating large areas of low to moderate copper accumulation, particularly in natural water bodies, wetlands, and riparian zones.
Pros and Cons	▪ Phytoremediation is environmentally friendly and cost-effective. ▪ However, it is a slower process and may not be suitable for areas with high levels of copper or where rapid copper removal is necessary.

REVERSE OSMOSIS

Mechanism	▪ Water is forced through a semi-permeable membrane that blocks dissolved substances, including copper, allowing only water molecules to pass through.
Application	▪ Reverse osmosis is used for desalination and producing high-purity water, including in municipal water treatment plants[4].
Pros and Cons	▪ Reverse osmosis is highly effective but can be expensive due to high energy requirements and the need for membrane maintenance. ▪ It is best suited for treating small volumes of water with high purity requirements.

[3] Enochs, B., Meindl, G., Shidemantle, G., Wuerthner, V., Akerele, D., Bartholomew, A., Bulgrien, B., Davis, A., Hoyt, K., Kung, L., Molina, M., Miller, E., Winship, A., Zhang, Y., Graney, J., Collins, D., & Hua, J. (2023). Short and long-term phytoremediation capacity of aquatic plants in Cu-polluted environments. *Heliyon*, *9*(1), e12805. https://doi.org/10.1016/j.heliyon.2023.e12805

[3]Ab Hamid, Nur Hafizah, Muhamad Iqbal Hakim bin Mohd Tahir, Amreen Chowdhury, Abu Hassan Nordin, Anas Abdulqader Alshaikh, Muhammad Azwan Suid, Nurul 'Izzah Nazaruddin, Nurul Danisyah Nozaizeli, Shubham Sharma, and Ahmad Ilyas Rushdan. 2022. "The Current State-Of-Art of Copper Removal from Wastewater: A Review" *Water* 14, no. 19: 3086. https://doi.org/10.3390/w14193086

ACTIVATED CARBON FILTERS

Mechanism	▪ Activated carbon is used to adsorb copper ions from water[1]. The large surface area of activated carbon makes it highly effective at trapping contaminants.
Application	▪ Activated carbon filters are commonly used in household water filtration systems and in industrial settings where water needs to be purified from various contaminants, including copper.
Pros and Cons	▪ Activated carbon filters are easy to use and effective for removing low to moderate levels of copper. ▪ However, they require regular replacement or regeneration of the carbon material, which can increase operational costs.

COMPARISON OF TECHNIQUES

- **Effectiveness**: All methods are effective at removing copper, but their suitability varies depending on copper concentration, water volume, and specific water quality requirements. Reverse osmosis offer the highest removal efficiency but at a higher cost, while limestone addition and chemical precipitation are more cost-effective for larger volumes with moderate copper levels.
- **Environmental Impact**: Phytoremediation is the most environmentally friendly option, offering sustainable, long-term solutions with minimal ecological disruption. However, it may not be fast enough for urgent or high-volume copper removal needs. Limestone addition, while effective, occasionally requires temporary management of pH levels to avoid negative impacts on aquatic life.
- **Cost**: Reverse osmosis is the most expensive due to equipment and maintenance needs. Limestone addition and chemical precipitation are more affordable but may require secondary treatment for sludge or precipitates. Phytoremediation, while lower in cost, requires longer time frames to achieve significant copper reduction.

CONCLUSION

Removing excess copper from water may be important for protecting aquatic ecosystems and ensuring safe water for human consumption. The choice of technique depends on the specific context, including copper concentration, water volume, and environmental considerations. Limestone addition offers an effective and affordable solution, especially in waters with varying pH levels. This method is the most cost-effective, particularly on a large scale. It is also the most effective strategy for copper sequestration in large water bodies, and requires minimal operational costs.