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APPLICATION OF COPPER FOAMS FOR THE WATER PURIFICATION PROCESS: A REVIEW

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Abstract

Water contamination by toxic hexavalent chromium (Cr(VI)) represents a critical global challenge, requiring efficient and sustainable remediation technologies. Conventional removal methods are often limited by surface passivation and the risk of excessive metal leaching. This paper reviews the application of open-cell copper foams synthesized via an eco-friendly space-holder technique using raw cane sugar for the removal of Cr(VI) from drinking water. The foams, featuring 65% porosity, achieved complete Cr(VI) removal at pH levels up to 7.2 through a redox mechanism. Results indicate that removal efficiency improves with smaller pore sizes, confirming copper foam's potential as a sustainable solution for practical water purification.

***Keywords**: metal foams, drinking water, copper foams, chromium(VI)*

1. INTRODUCTION

Water pollution and the resulting lack of clean water have emerged as critical global issues that must be seriously considered because the life and health of both humans and animals are gravely endangered. This crisis often occurs as a direct consequence of rapid economic development [1,2]. Contaminated water is a primary vector for transmitting devastating diseases, representing a leading cause of infectious death in children younger than five years [2,3]. Chromium(VI) contamination of water originates mainly from industrial activities such as electroplating, leather tanning, stainless steel production, pigment manufacturing and mining operations. During these processes, Cr(VI)-containing compounds can be released into wastewater and discharged into surface and groundwater systems. Improper storage and disposal of industrial waste, leakage from landfills, and runoff from contaminated sites represent additional sources of pollution [4]. Unlike Cr(III), which is an essential trace element in small amounts, Cr(VI) is highly soluble, mobile, and toxic, allowing it to migrate easily through aquatic environments and pose risks to ecosystems and human health. The removal of heavy metals like hexavalent chromium Cr(VI) is a major concern, as conventional adsorption methods often suffer from surface passivation, restricting their long-term efficiency.

Consequently, there is an urgent need for an effective, eco-friendly, and energy-efficient alternative water treatment technology [5].

By optimizing the foam's structural parameters, specifically achieving 65% porosity with pore sizes ranging from 0.3 to 0.5 mm, the study reveals that smaller pores significantly increase the specific surface area, allowing for complete Cr(VI) removal at pH values as high as 7.2. The process of Cr(VI) removal is driven by a redox mechanism in which the copper surface serves as an electron donor, through reduction of Cr(VI) to less toxic and less soluble Cr(III) species that are captured and distributed homogeneously within the interconnected porous network. Ultimately, these copper foams provide a robust, long-lasting, and cost-effective solution for water purification, maintaining high efficiency and structural stability while ensuring minimal metal leaching into the treated water [6].

This research investigates the application of open-cell copper foams, synthesized via an environmentally friendly space holder technique using crystalline raw cane sugar, as high-performance filter beds for the removal and reduction of hexavalent chromium Cr(VI) in drinking water.

2. APPLICATION OF METAL FOAM FOR WATER PURIFICATION PROCESS

The permissible concentration of chromium in drinking water is generally regulated as total chromium. The WHO guideline value for total chromium is 50 μg/L. Due to its high toxicity and carcinogenic potential, Cr(VI) is considered the most critical chromium species in contaminated water systems [7]. A commonly applied treatment approach for reducing residual Cr(VI) concentrations in drinking water is chemical coagulation using iron salts, where Fe(II) reduces Cr(VI) to the less soluble Cr(III), which is subsequently removed by coagulation and filtration processes [8]. Besides iron, metals such as Al, Cu, Mg, Ni, and Zn, in the form of powders or granulated materials, represent the class of the most important adsorbents for Cr(VI) removal from water. Although they have proven to be a highly efficient and economical choice, their main drawback is surface passivation that occurs after short-term use. Therefore, it is necessary to utilize materials that possess the ability to "self-regenerate," such as Cu-Zn alloys. However, as a consequence of the high solubility constant of Zn, a serious undesirable effect occurs, namely their excessive leaching into the treated water [9].

As previously mentioned, open-cell metal foams have found applications in water treatment processes. Previous studies investigated the efficiency of copper foam for the removal of hexavalent chromium from water. Copper foams act as electron donors and participate in redox reactions, allowing their application for the removal of heavy metals and providing antimicrobial properties in drinking water purification. Standard methods for Cr(VI) removal from water usually involve its reduction to Cr(III), specifically into insoluble oxide (Cr_2O_3) or hydroxide ($Cr(OH)_3$), whereas the use of copper foams eliminates the need for this intermediate step because the Cu surface continuously provides electrons for Cr(VI) reduction. Metal foams offer several advantages over the aforementioned alloys, such as a longer lifespan before replacement and a compact structure that ensures better chemical stability. Furthermore, open-cell metal foams possess high porosity, which extends the contact period of the water with the porous surface.

It is of great importance to develop a simple, environmentally friendly and economical synthesis method for open-cell metal foams that enables control over foam porosity and pore size. Among the various approaches for preparing metal foams, the space holder technique is the most commonly used. NaCl particles are among the most prominent materials used as space holders. Considering that residual NaCl particles can cause undesirable corrosion of the metal matrix, raw cane sugar was used as an innovative space holder in the work of Stergioudi et al. By using a sugar volume percentage of 70–80% with particle sizes in the range of 0.35–0.70 mm and a method involving mixing, compaction, water leaching, and sintering at 840°C, a foam with 65% porosity, high structural stability, and enhanced interconnectivity of macropores, necessary for the free flow of treated water, is obtained. Smaller sugar particles ensure a smaller pore size and a higher specific surface area. One of the main advantages of sugar over other space holder materials is that it is environmentally friendly, meaning it does not employ toxic, flammable, or explosive materials at any stage of the manufacturing process. Unlike carbonate-based space holders, whose removal by heating releases environmentally hazardous gases, raw sugar holders are easily removed by leaching in water at room temperature. Sugar does not cause corrosion in the foam material, and its high availability and low cost further facilitate its application. Elemental copper powder (99% purity) used as the starting material in combination with the sugar space holder results in copper foams with an extended operational lifetime of use, whose efficiency as filter-beds for the removal of Cr(VI) from water is described below.

The water used for testing was prepared to simulate natural water with its typical characteristics, spiked with 100 μg/L Cr(VI). Throughout the testing period, a stable pH value of 6–8 was maintained, and the water flow rate was 100 mL/h. The residual concentration of Cr(VI) in the water was determined by the diphenylcarbazide method using a Hitachi U-5100 UV/VIS spectrophotometer. Total concentrations of Cr and Cu were measured by graphite furnace atomic absorption spectrophotometry using a Perkin Elmer Analyst 800 instrument.

Over a period exceeding one month, copper foam samples were tested in column tests to determine their efficiency in removing Cr(VI) from water. Figure 1 [6] shows the results related to the residual concentrations of Cr(VI) in water treated with copper foams of the same porosity but different mean pore sizes of 0.3 and 0.5 mm at various pH values. Based on the results, it can be concluded that both samples showed greater efficiency at pH values below 6.5, where Cr(VI) was completely removed, while an alkaline environment (pH > 7) complicates the reduction of Cr(VI). The breakpoint for the sudden increase in residual chromium for copper foams with a pore size of 0.5 mm is at pH 6.8, whereas for samples with a pore size of 0.3 mm, this point is at 7.2. This phenomenon can be explained by the fact that the nearly doubled specific surface area results in a longer "effective" contact time. It should be noted that during the reduction of Cr(VI), there is a gradual dissolution of Cu^{2+} into the treated water, but also a regeneration of the metal surface via Cu^{0}. The deposition or adsorption of Cr(VI) continues onto the freshly formed Cu^{0} sites. The dissolution of the copper foam may be a limiting factor for its use [6].

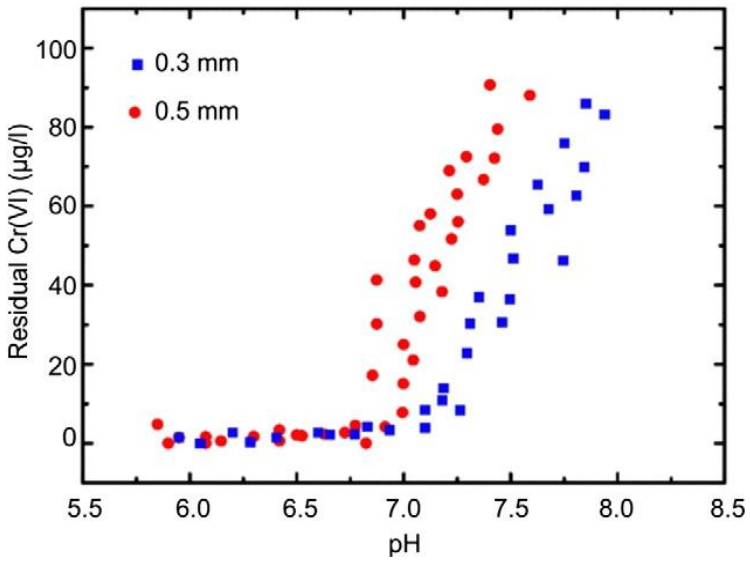


Figure 1. *Residual Cr(VI) concentration in treated water as a function of water pH for the two tested Cu-foams with mean pore sizes of 0.3 and 0.5 mm [6]*

Figure 2a [6] was obtained by SEM analysis of a cross-section of the copper foam with a mean pore size of 0.5 mm. From the image, it can be concluded that the distribution of "captured" chromium throughout the volume of the copper foam is fairly homogeneous. However, higher magnification SEM images revealed two different morphologies on the surface of the copper foam cell walls. Figure 2b [6] shows a rough morphology in the form of numerous protruding crystalline nodules interspersed with a small number of smooth areas. Additionally, smooth regions embedded in the porous structure were also observed (Figure 2c [6]). Using SEM-EDS analysis, which serves to identify the elemental composition of the sample, it was determined that the smooth surfaces consist of almost pure copper, while the crystalline nodules are rich in Cr [6].

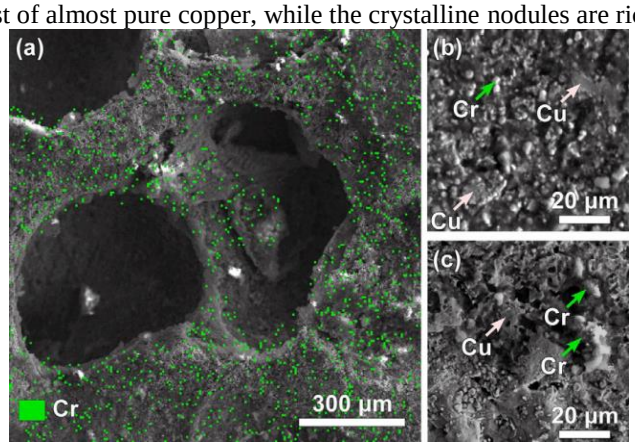


Figure 2. *(a) SEM-EDS image of Cu-foam with a pore size of 0.5 mm. High magnification SEM images with (b) rough and (c) smooth morphologies [6]*

3. CONCLUSION

Recent progress has highlighted open-cell metal foams as high-performance filter beds for the removal of heavy metals [4]. This review focuses on copper foams, which offer unique advantages such as high structural stability, low density and a very high specific surface area reaching values as high as 2131 mm^2/g. The development of these low-cost and efficient adsorbents is facilitated by innovative, environmentally friendly synthesis techniques, such as the "space holder" method using raw cane sugar, which provides precise control over porosity and pore size. Experiments confirm that copper foams are highly effective for the removal of hexavalent chromium Cr(VI), acting as electron donors in redox reactions that convert toxic ions into insoluble oxides. Their effectiveness depends on parameters such as pore size (0.3–0.5 mm) and pH levels, with complete removal achievable at values as high as 7.2. While these foams provide a robust and long-lasting solution, the gradual dissolution of copper into treated water must be carefully monitored as a potential limiting factor for mass-scale application [6]. Future studies should focus on large-scale application and long-term monitoring of copper leaching under practical operating conditions.

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REFERENCES

[1] Liu, K. Zhang, Y. Son, W. Zhang, L. M. Spindler, Z. Han, L. Ren, Journal of Materials Chemistry A, 5 (2017) 2603-2612.

[2] L. Yue, S. Chen, S. Wang, C. Wang, X. Hao, Y. F. Cheng, Environmental Science: Nano, 6 (2019) 2801-2812.

[3] J. Zhao, P. Yan, B. Snow, R. M. Santos, Y. W. Chiang, Process Safety and Environmental Protection, 142 (2020) 191-202.

[4] A. K. Shanker, C. Cervantes, H. Loza-Tavera, S. Avudainayagam, Environment International, 31 (2005) 739–753.

[5] J. Kotas, Z. Stasicka, Environmental Pollution, 107 (2000) 263-283.

[6] F. Stergioudi, E. Kaprara, K. Simeonidis, D. Sagris, M. Mitrakas, G. Vourlias, N. Michailidis, Materials and Design, 87 (2015) 287-294.

[7] World Health Organization, Guidelines for Drinking-water Quality, 4th ed., Geneva, 2017.

[8] C. Pan, L. D. Troyer, J. G. Catalano, D. E. Giammar, Environmental Science & Technology, 50 (2016) 13502-13510.

[9] E. Kaprara, P. Seridou, V. Tsiamili, M. Mitrakas, G. Vourlias, I. Tsiaoussis, G. Kaimakamis, E. Pavlidou, N. Andritsos, K. Simeonidis, Journal of Hazardous Materials, 262 (2013) 606-613.