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The International Scientific and Professional Conference POLITEHNIKA 2023 represents the seventh edition of the POLITEHNIKA scientific and professional events, occurring biannually since its inaugural event in 2011. POLITEHNIKA 2023 upholds a distinguished tradition and commitment to integrating higher education and practical application across a diverse spectrum of disciplines represented by defined thematic scopes.

Organized with the patronage of the Ministry of Education of the Republic of Serbia, the Ministry of Environmental Protection of the Republic of Serbia, the Ministry of European Integration of the Republic of Serbia, the Directorate for Occupational Safety and Health, the Office for Dual Education and National Qualifications Framework, the Conference of Academies of Applied Studies in Serbia, the Chamber of Commerce of Serbia, the Chamber of Commerce of Belgrade, the Institute for Standardization of Serbia, the Association of Belgrade Architects, the City of Požarevac and the Tourist Organization of the City of Požarevac, POLITEHNIKA 2023 stands as a collaborative platform at the intersection of academia, governmental institutions and industry.

This year heralds a notable progression with its international status and the incorporation of 10 conference scopes. Expanding beyond the thematic domains featured in previous events, the Conference now encompasses Environment and Sustainable Development, Occupational Safety and Health and Fire Safety, Smart Management Systems, Graphic Engineering, Design, Traffic Engineering, Biotechnology and Healthcare, Mechanical Engineering, Ecotourism and Rural development, and Mechatronics. By engaging experts, emerging professionals, and practitioners from these domains, the conference unifies fields of study programs of the Academy of Applied Technical Studies Belgrade. The thematic scopes, coupled with the structure of the compiled papers in this Proceedings, exhibit a rich diversity and multidisciplinary approach, fundamentally contributing to a holistic examination and resolution of societal and scientific challenges.

Comprising over 220 peer-reviewed contributions, the Proceedings represent a substantial intellectual asset, aligning with the conference's overarching objective of fostering the exchange of knowledge, research findings, and professional experiences among experts from industry, research institutions, and higher education establishments.

The Proceedings of the International Scientific and Professional Conference POLITEHNIKA 2023 serve as a comprehensive snapshot of the current landscape within the thematic realms of the conference, offering both insights and directives for ongoing scientific and professional development. Moreover, they proffer concrete solutions to practical challenges grounded in contemporary trends and pertinent insights.

The Academy of Applied Technical Studies Belgrade extends its sincere appreciation to all conference supporters whose financial contributions played a pivotal role in its successful realization. Special acknowledgment is reserved for the authors of the papers, whose diligence and eagerness to present their work to a wider audience, alongside the reviewers and members of the International Scientific Committee, Program Committee and Organizational Committee, have collectively contributed to the triumph of the International Scientific and Professional Conference POLITEHNIKA 2023.

Belgrade, December 2023
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Andrea Matta, PhD, Dept. of Mechanical Engineering, Politecnico di Milano, Italy Mohsen Jafari, PhD, Dept. of Industrial and Systems Engineering, Rutgers University, USA
Towards a theory of digital twins: fundamental definition

TABLE OF CONTENTS

SCOPE 1. ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

STUDENTS PAPER

SCOPE 2. OCCUPATIONAL HEALTH AND SAFETY AND FIRE SAFETY

STUDENTS PAPER

SCOPE 3. SMART MANAGEMENT SYSTEMS

SCOPE 4. GRAPHIC ENGINEERING

SCOPE 5. DESIGN

STUDENTS PAPERS

SCOPE 6. TRAFFIC ENGINEERING

STUDENT PAPER

SCOPE 7. BIOTECHNOLOGY AND HEALTHCARE

SCOPE 8. MECHANICAL ENGINEERING

SCOPE 9. ECOTOURISM AND RURAL DEVELOPMENT

STUDENT PAPER

SCOPE 10. MECHATRONICS

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ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

POTENTIAL APPLICATION OF MULLEIN LEAF AS BIOSORBENT FOR EFFICIENT BIOSORPTION OF CU(II) IONS FROM SYNTHETIC SOLUTIONS

Maja Nujkić[1], Technical Faculty in Bor, University of Belgrade
Žaklina Tasić, Technical Faculty in Bor, University of Belgrade
Sonja Stanković, Technical Faculty in Bor, University of Belgrade
Dragana Medić, Technical Faculty in Bor, University of Belgrade
Snežana Milić, Technical Faculty in Bor, University of Belgrade
Vladan Nedelkovski, Technical Faculty in Bor, University of Belgrade

Abstract: *In this study, the potential of mullein leaf (Verbascum Thapsus) as a ground powder for the biosorption of Cu(II) ions from synthetic solutions was examined. Several factors affecting the biosorption efficiency of mullein leaf powder were investigated, including the initial Cu(II) concentration (25–400 mg L^{-1}), solution pH (3–7), contact time (10–120 min.), and biosorbent dosage (2–20 g L^{-1}). The concentration of Cu(II) ions before and after biosorption using inductively coupled plasma optical emission spectrometer was determined. The biosorption efficiency of 58.74% was observed at a biosorbent dosage of 20 g L^{-1} and an initial Cu(II) concentration of 100 mg L^{-1}. Also, the good biosorption efficiency of 50.74% Cu(II) was reached at a contact time of 90 min. The optimal solution pH was determined to be 4, but the highest removal efficiency of 64.27% for Cu(II) was determined at pH=7. Thus, mullein leaf shows the potential of a cost-effective biosorbent for wastewater treatment, but further investigation of modified mullein will be applied.*
Keywords: Biosorption, Non-toxic plant biomaterial, Copper(II)

1. INTRODUCTION

Heavy metals in polluted waters and industrial effluents are considered as a threat to living organisms and may cause many diseases. Among all existing metals, copper is included in the group of essential trace elements, but high concentrations of copper are toxic to most life forms [1, 2]. In recent years, detailed studies on the copper impacts to human health have been conducted and because of adverse effects, significant research has been performed for treatments of removing copper from contaminated water [3]. Some of the proposed treatment methods were: ion exchange, adsorption, membrane separation etc. These conventional methods require high investment, and that is why researchers focus on the use of low-cost and locally-available materials for cheaper and environmentally friendly methods for water treatment [4]. Such a method is biosorption, treatment that uses sorbent materials with high binding affinity and surface area [5]. Various biosorbents can be used for copper-containing wastewater treatment, such as agricultural waste, which includes walnut, pistachio, rice straw, corn, orange, pine cone, straw, tea waste, local seashells etc. [6]. Mullein (*Verbascum thapsus*) is a tea waste generated from local tea supplier after the expiration date. According to the [2] mullein surface has C–H, C–O, O–H, C=O and COO– groups that can be used for the binding of metals; it also contains phenol, alkaloids, tannins, saponins, flavonoids, and triterpenoids.
The purpose of this study was to investigate the use of mullein leaves powder as biosorbent for the removal of Cu(II) ions from synthetic solutions.

[1] mnujkic@tfbor.bg.ac.rs

2. MATERIALS AND METHODS

The stock solution of copper sulfate (1 g L^{-1} Cu(II)) was prepared using deionized water. Samples of washed, dried and grounded mullein were collected from a local supplier of tea, Adonis, Serbia. Additionly, waste mullein was previously grounded in a blender, and then sieved to get particle size below 1 mm. Prepared biosorbent was stored in the paper bags until biosorption experiments.

2.1 Biosorption experiments

The biosorption of Cu(II) ions using waste mullein was performed in copper synthetic solutions (50 mL of each solution), at room temperature. The effects of initial biosorbent dosage (2–20 g L^{-1}), contact time (10–120 min.), solution pH (3–7), and initial Cu(II) concentration (25–400 mg L^{-1}) on biosorption were investigated, at a speed of 600 rpm. After filtration, Cu(II) ions concentration in treated sample solutions, were determined using an inductively coupled plasma optical emission spectrometer (ICP-OES Optima 8300; Perkin Elmer, USA). Biosorption efficiency (E, %) and adsorption capacity (q, mg g^{-1}) of waste mullein were determined using equation (1) and (2), respectively [4]:

$$E\ (\%) = \frac{C_0 - C_e}{C_0} \times 100 \quad (1)$$

$$q = \frac{C_0 - C_e}{m} \times V \quad (2)$$

where *Co* and *Ce* are initial and equilibrium Cu(II) concentrations in the synthetic solution (mg L^{-1}), *m* is mass of waste mullein (g) and *V* is volume of Cu(II) solution (L).

3. RESULTS AND DISCUSSION

3.1 Effect of biosorbent dosage

The effect of the biosorbent dosage of mullein on the removal of Cu(II) ions from the synthetic solution was investigated with five different biosorbent dosages (2, 8, 12, 16, 20 g L^{-1}) under the following conditions: contact time 90 min, solution pH = 4, temperature at 25°C, and initial Cu(II) ion concentration 100 mg L^{-1} (Fig. 1). The results showed that increasing mullein dosage until an effective level of 20 g L^{-1} enhanced the adsorption efficiency of Cu (II) ions, resulting in a biosorption efficiency of 58.74% for Cu (II) ions. This may be a result of the initially available active sites and negative surface charge of the mullein which can favour electrostatic attraction between sorbent and solute [7]. As can be seen in Fig. 1., as the biosorbent dosage increases, the adsorption capacity considerably decreases. Consequently, increasing the amount of mullein biomass gradually increases the final removal of metal ions, but it also leads to reduction of active sites and adsorption capacity of mullein [8]. Therefore, the optimum mullein dosage was achieved at 20 g L^{-1} for further experiments analysis.

3.2 Effect of contact time

The effect of contact time (10, 40, 60, 90, 120 min.) for biosorption of Cu(II) ions at pH = 4 for initial metal concentration of 100 mg L^{-1} by using 20 g L^{-1} of mullein was investigated and shown in Fig. 2. The results indicated slower increase of biosorption efficiency and adsorption capacity of mullein till a good degree of adsorption was achieved at 90 min for Cu(II) ions. The maximum biosorption efficiency and adsorption capacity at contact time were 50.74% and 2.54 mg g^{-1} for Cu(II), respectively. After 90 min., the biosorption rate decreases because the equilibrium condition was

achieved due to repulsive forces on the mullein surface [4]. The optimal contact time of 90 min was used for further analysis.

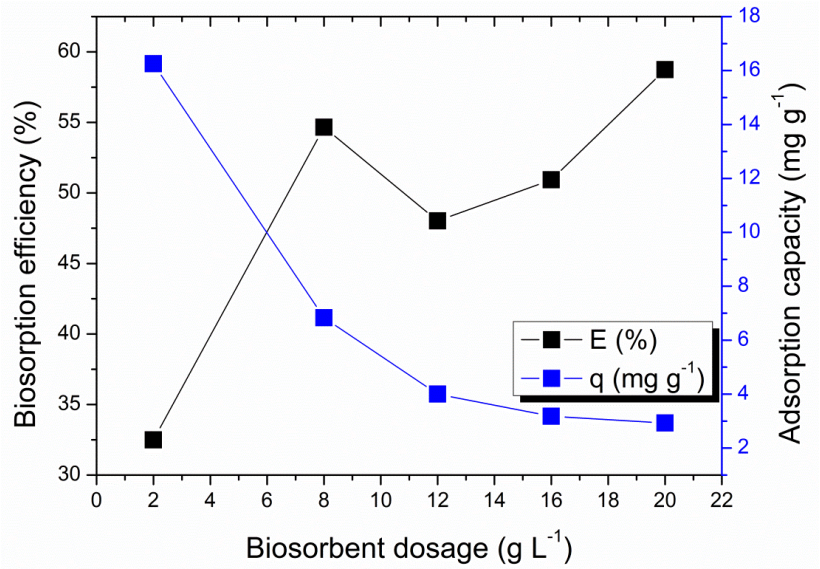

Figure 1. Effect of biosorbent dosage on adsorption capacity and efficiency of Cu(II) ions from synthetic solutions

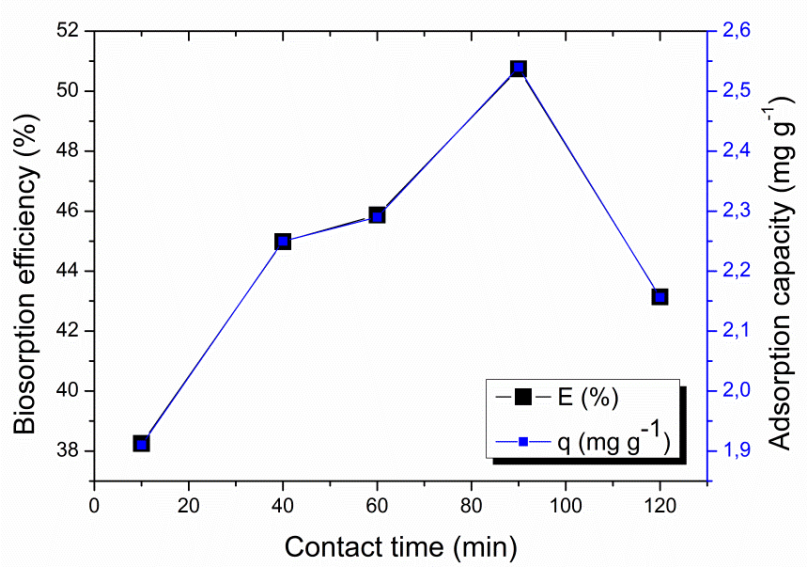

Figure 2. Effect of contact time on adsorption capacity and efficiency of Cu(II) ions from synthetic solutions

3.3 Effect of solution pH

Biosorption processes are highly pH dependent, because H^+ ion concentration may influence the charged biosorbent surface and the ionization degree of various contaminates. The effects of initial pH (3, 4, 5, 6, 7) on biosorption efficiency of Cu(II) ions were investigated by optimal contact time at 90 min and an initial Cu(II) concentration of 100 mg L^{-1} by using 20 g L^{-1} mullein. The biosorption efficiency of Cu (II) ions was raised by increasing the pH values, as shown in Figure 3.

Based on the results, it can be observed that the highest biosorption efficiency and adsorption capacity were observed at pH = 7. At higher pH, biosorption of Cu(II) ions can occur under the lower H^+ ion concentration, which further produces more negatively charged binding sites. This could free the functional groups on mullein surface, and in this way can be more suitable for Cu(II) ions adsorption

[5, 9]. The finding wasn't in agreement with the recently published result [2], where for the optimal pH value for Cu(II) biosorption using grounded mullein particle size below 2 mm, was 4.

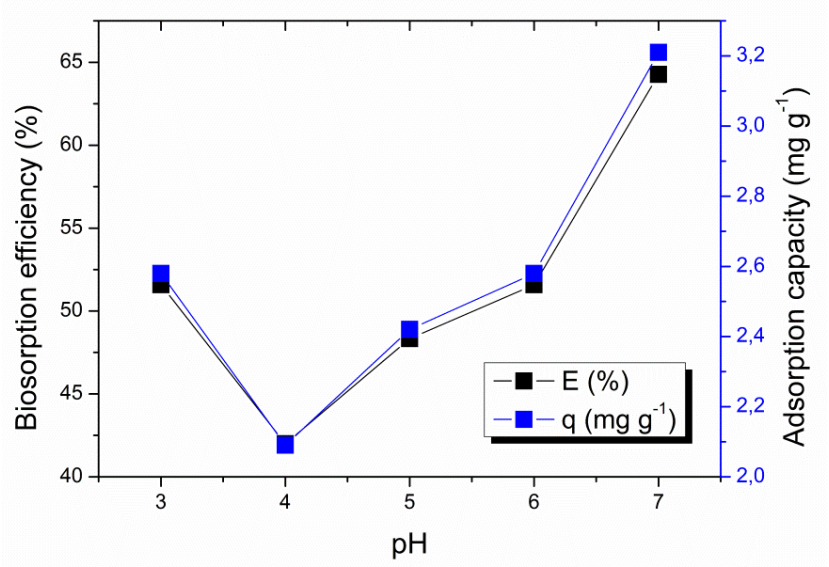

Figure 3. Effect of pH on adsorption capacity and efficiency of Cu(II) ions from synthetic solutions

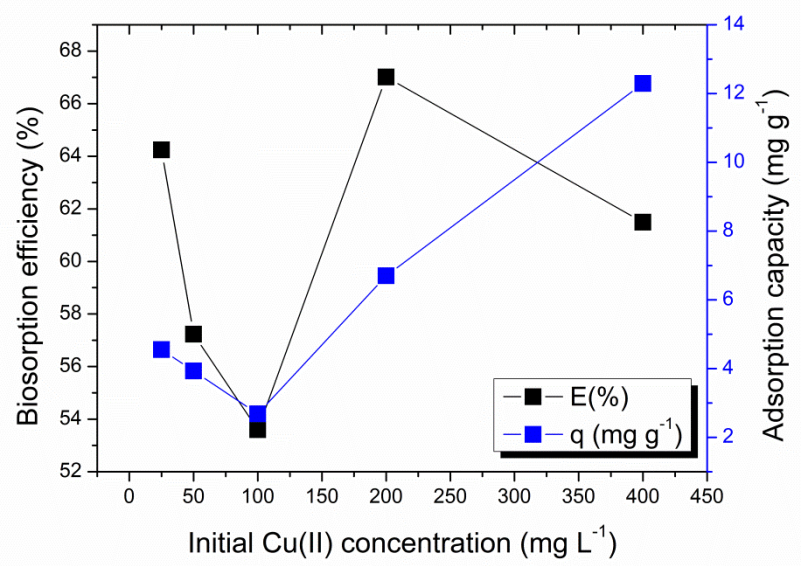

Figure 4. Effect of the initial Cu(II) concentration on adsorption capacity and efficiency of Cu(II) ions from synthetic solutions

3.4 Effect of the initial Cu(II) ions concentration

Initial Cu(II) ions concentration (25, 50, 100, 200, 400 mg L^{-1}) effect on biosorption efficiency of mullein was studied at previously optimized parameters (pH = 4, temperature of 25°C, contact time 90 min, and biosorbent dosage of 20 g L^{-1}). The results are presented in Fig. 4. It can be observed that an increase in the initial Cu(II) ion concentrations from 25 to 100 mg L^{-1}, leads to a decrease in biosorption efficiency and adsorption capacity. However, a further increase in the Cu (II) concentration resulted in an increase in Cu(II) removal. The highest removal efficiency (67.01%) of Cu(II) ions was observed with an initial Cu(II) ions concentrations of 200 mg L^{-1}. The results indicated that mullein gives maximum removal potential for Cu(II) ions at their higher initial concentrations. Higher initial concentrations lead to quick saturation of the mullein binding sites because the quantity of biosorbent stays constant [4]. However, a further increase in the Cu(II)

concentration resulted in a biosorption efficiency decrease. It can be seen that the highest removal efficiency (67.01%) using 20 g L^{-1} mullein was lower than results, given in our previously published paper [2], of copper removal (~79%) for 2 g L^{-1} mullein. Therefore, the initial Cu(II) ions concentrations of 100 mg L^{-1} was utilized for further experimental analysis.

4. CONCLUSION

This study presents the use of natural resource, a nontoxic edible plant and cost-effective biosorbent in wastewater treatment for biosorption of Cu(II) ions from synthetic solutions. Mullein with biosorbent dose of 20 g L^{-1} showed a good potential for biosorption of Cu(II) ions as compared to mullein with biosorbent dose of 2 g L^{-1}. Precisely, the maximum removal of Cu(II) ions was 67.01% at the initial Cu(II) ions concentration of 200 mg L^{-1}. Overall, it could be inferred that 2 g L^{-1} mullein was able to remove Cu(II) ions more effectively from Cu(II) solutions than the mullein of 20 g L^{-1} under the same conditions (pH=4, t=25°C, contact time of 90 min., and initial Cu(II) ions concentrations of 100 mg L^{-1}). For further investigations, the mullein could be examined under other various conditions or as new modified sorbent under the same conditions.

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