



University of Belgrade, Technical Faculty in Bor
29th International Conference Ecological Truth
& Environmental Research



EcoTER'22

Proceedings



Editor

Prof. Dr Snežana Šerbula

21-24 June 2022, Hotel Sunce, Sokobanja, Serbia



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PREFACE

In today's world, the environment has been endangered by the use of outdated technology, fossil fuels and environmental law violations. Therefore, environmental and many other scientists all over the world have been concerned about finding sustainable technology in resolving these issues. That is why environmental research and ecological truth are at the focus of the 29th International Conference Ecological Truth & Environmental Research 2022 (EcoTER'22), which will be held in Sokobanja, Serbia, 21–24 June 2022. On behalf of the Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the Conference.

We hope to convey the message of the conference, which is that a transformation of attitudes and behavior would bring the necessary changes. This is also an opportunity for the participants who are experts in this field to exchange their experiences, expertise and ideas, and also to consider the possibilities for their collaborative research.

The 29th International Conference Ecological Truth & Environmental Research 2022 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology, the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica, the University of Zagreb, Faculty of Metallurgy – Sisak, the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Association of Young Researchers, Bor.

These proceedings include 85 papers from the authors coming from the universities, research institutes and industries in 6 countries: Bulgaria, Italia, Albania, Bosnia and Herzegovina, Montenegro and Serbia.

As a part of this year's conference, the 4th Student section – EcoTERS'22 is being held. We appreciate the contribution of the students and their mentors who have also participated in the Conference.

Financial assistance provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia is gratefully acknowledged by the Organizing Committee of the EcoTER'22 conference.

The support of the Platinum donor and their willingness and ability to cooperate have been of great importance for the success of EcoTER'22. The Organizing Committee would like to extend their appreciation and gratitude to the Platinum donor of the Conference for their donation and support.

We appreciate the effort of all the authors who have contributed to these Proceedings. We would also like to express our gratitude to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the Conference participants for their support to EcoTER'22. Sincere thanks go to all the people who have contributed to the successful organization of EcoTER'22.

Prof. Snežana Šerbula,

President of the Organizing Committee

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BIOSORPTION OF METAL IONS FROM SYNTHETIC SOLUTIONS USING DIFFERENT PARTS OF PLANT MATERIAL – A REVIEW

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Abstract

In recent years, increasing water pollution with heavy metals from anthropogenic sources has been observed. Heavy metals can be extremely toxic to living organisms and for that reason it is necessary to find an adequate method of water purification. Biosorption has proven to be a very favorable method for removing heavy metals from polluted water with a number of advantages over conventional methods. This paper presents an overview of scientific research on the application of eight different biosorbents for the removal of the most common heavy metals from water. The aim of this paper is to determine the basic characteristics of biosorbents (metal removal efficiency, capacity) and the influence of various factors (amount of biosorbent, particle size, pH value, contact time, temperature, initial concentration of metals in solution) on biosorption.

Keywords: Biosorption, biosorbents, heavy metals

INTRODUCTION

Water is the most important resource that enables the presence of life on earth and access to clean water is important for people and the entire ecosystem. Heavy metal ions are among the pollutants that are released in large quantities into the environment and therefore cause great concern [1]. Trace elements such as heavy metals can occur in both surface and groundwater's as a result of the impact of several anthropogenic activities (*e.g.* agriculture, energy producing, industry, manufacturing, mining, etc.) [2]. Mining and industrial processing for the purpose of extracting mineral raw materials and their later application in industry and agriculture have led to an increase in the concentration of heavy metals in biochemical cycles [3]. Use of biological materials, *i.e.* biosorbents, have been important in recent years [4]. The biosorption method reduces operating costs by 36%, investment costs by 20% and total costs by 28% compared to standard methods. As a result, interest in the application of this cheap method is growing [5].

BIOSORPTION OF HEAVY METALS FROM WATER USING DIFFERENT BIOSORBENTS

Agricultural waste can be used as a biosorbent with very little processing. It has been observed that HCl-treated tomato waste can remove 92.08% of Cu(II) ions from a 50 ppm solution. These results were achieved under optimal conditions: biosorbent mass (0.2 g), solution volume of Cu(II) ions (50 mL) and pH=8. Langmuir adsorption isotherm was found to best fit the adsorption data, and reaction kinetic was best described by pseudo-second order. By increasing the mass of the biosorbent, there was a slight increase in the removal efficiency of Cu(II) ions and a decrease in the adsorption capacity of the biosorbent (q_e), as shown in Figure 1 [6].

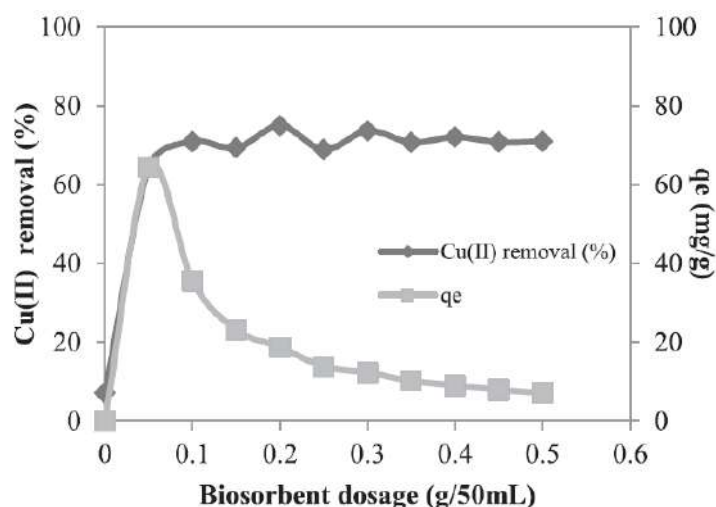


Figure 1 Effect of tomato waste biosorbent dosage on Cu(II) ions biosorption (pH=8, Cu(II) ions concentration: 100 mg L^{-1} , temperature: 293 K, contact time: 1h) [6]

It has been found that brown algae (*Sargassum sp.*) can be successfully used to remove nickel and copper ions from both synthetic water solutions and electroplating effluents. Maximum biosorption capacity for water solution was $1.404 \text{ mmol L}^{-1}$ for Ni(II) ions and $1.656 \text{ mmol L}^{-1}$ for Cu(II) ions. After regeneration of the biosorbent, it retained 75% of the initial biosorption capacity. During biosorption from the effluent, a reduction in capacity of 29.69% for Ni(II) and 26.24% for Cu(II) ions was observed in comparison with synthetic solution. Nonetheless, the high biosorption efficiency of brown algae makes it a very effective biosorbent for removing heavy metals from water [7].

In the study of removal of Cu(II) ions from water using algae *Codium vermilara*, it was found that it is possible to remove 85.5% of Cu(II) ions, under optimal conditions (biosorbent mass: 0.75 g, initial copper concentration: 48.75 mg L^{-1} , pH=5.28, contact time: 70.51 min). Scanning electron micrograph (SEM) analysis (Figure 2) confirmed the presence of pores on the algal biosorbent, which contributes to higher biosorption efficiency. Morphological changes on the surface of the biosorbent were also observed, after the binding of Cu(II) ions [8].

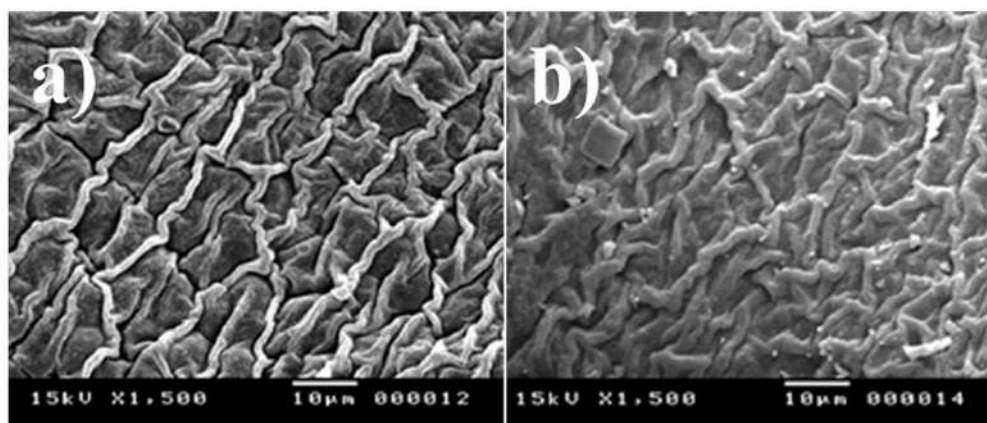


Figure 2 Scanning electron micrograph of *C. vermilara* biosorbent a) before and b) after biosorption of Cu(II) ions [8]

Alium Cepa seeds were found to have a good biosorption properties when removing heavy metal ions like Cu(II), Cr(VI), Zn(II), Pb(II) and Cd(II) from water effluents. In order to better understand binding mechanisms of *Alium Cepa* seeds, authors conducted Fourier-transform infrared spectroscopy and scanning electron micrograph analysis, which confirmed porousness of biosorbent surface and presence of OH⁻ i COOH⁻ functional groups. Optimal experiment conditions were found to be: biosorbent mass (0.4 g), initial metal concentration (50 mg L⁻¹) and pH=7. Optimal biosorption time for Cu(II), Cd(II) and Pb(II) were 90 min, and for Zn(II) and Cr(VI) 120 min. By fitting the experimental data in Freundlich and Langmuir isotherms (Table 1), Langmuir model had bigger regression coefficient and fitted the best [4].

Table 1 Regression coefficients (R^2) of Langmuir and Freundlich isotherms for ions Cr(IV), Cd(II), Zn(II), Cu(II) and Pb(II) [4]

	Cr(IV)	Cd(II)	Zn(II)	Cu(II)	Pb(II)
R² (Langmuir)	0.99	0.97	0.95	0.97	0.90
R² (Freundlich)	0.98	0.79	0.86	0.88	0.87

Tea is second most popular drink after water and its large consumption creates a lot of tea waste material. The experiment conducted by Shah *et al.* [9] aimed to determine the effectiveness of using tea leaves (*Camellia sinensis*) treated with formaldehyde as a biosorbent to remove Ni(II) ions from water. It has been found that formaldehyde can increase biosorption capacity and can prevent leaching of organic matter from biosorbents, thus preventing further pollution of water. At optimal biosorption conditions (biosorbent mass: 0.13 g, biosorption time: 90 min, pH=7) it was observed 100% of Ni(II) ions removal efficiency. By shaking samples, biosorption of Ni(II) ions was increased by 10%. No interfering effect from other ions was observed when conducting biosorption of Ni(II) ions from mixture of other ions (Na(I), K(I), Mg(II) and Ca(II)), thus making a *Camellia sinensis* tea waste an effective biosorbent for removing of Ni(II) ions from water [9].

The biosorbent obtained by carbonization of medicinal plants was tested for its removal efficiency of Zn(II), Pb(II) and Cd(II) ions from synthetic wastewater by the author Jan *et al.* [10]. Physical and chemical activation of carbonized biosorbent were conducted to increase biosorption efficiency, and it was found that physical activation using water vapor is more advantageous than chemical activation from the economic and environmental point of view. Optimum biosorbent carbonization conditions were observed at 650°C carbonization temperature, 60 min carbonization time. Maximum biosorption efficiency was 90%, reached at optimal biosorption conditions (biosorbent mass: 5 g L⁻¹ for Zn(II) and Pb(II), 4 g L⁻¹ for Cd(II), temperature: 25°C, contact time: 90 min, pH=5). Different efficiency of biosorption was observed depending on the type of water and the number of heavy metals. Lower biosorption removal efficiency was observed in multi element water in comparison with single element water, while the lowest biosorption efficiency of heavy metals was achieved in lechate, as shown in Figure 3 [10].

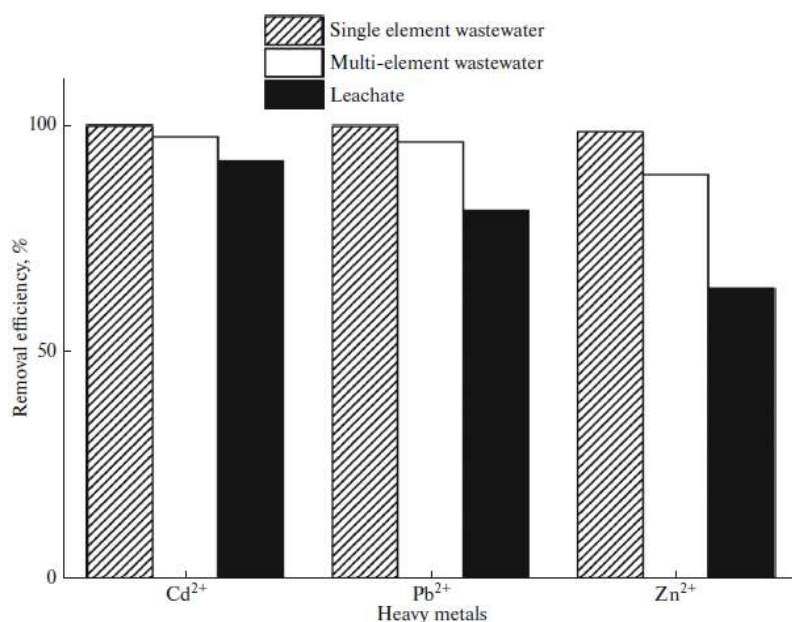


Figure 3 Biosorption removal rate of Cd(II), Pb(II) and Zn(II) ions depending on wastewater type and number of metals [10]

Ion exchange can significantly aid the biosorption process in removing Pb(II) and Cd(II) ions from water, as shown in research of Jokar *et al.* [11]. Chicory modified by CaCl₂ compound has a high biosorption capacity, reaching 123.5 mg g⁻¹ for Pb(II) ions and 64.5 mg g⁻¹ for Cd(II) ions. Thermal modification of chicory biosorbent must be performed at the lower and strictly controlled temperatures, because degradation and surface damage have been observed at temperatures above 25°C, which significantly reduces the biosorption capacity. The best ions removal rate was achieved with particle size of the biosorbent of 500 μm. Langmuir model best described the biosorption process. Metal recovery from biosorbent was attempted by using water, CaCl₂, HNO₃ and NaCl. In all cases, except using water, metal ions recovery was successful. This research has shown that chicory waste can effectively be used for removing Pb(II) and Cd(II) ions from water [11].

Use of Chinese sugar cane straw as a biosorbent for removing roxarson ($C_6H_6AsNO_6$), As(III) and As(V) ions from aqueous solution have been analyzed by Zang *et al.* [12]. Modification of biosorbent have been performed by $FeCl_3$ and with SEM analysis it was observed that mostly flat biosorbent surface became porous and wrinkled. The best results were obtained by using 1 g of biosorbent, at pH=5, biosorption temperature of 25°C. The experiment data best fitted the Langmuir, and the biosorption reaction took place according to the pseudo-second order kinetic model of the process. Maximum biosorption capacities per gram of biosorbent were: 12.4 mg g⁻¹ for roxarson, 5.3 mg g⁻¹ for As(III) and 23.0 mg g⁻¹ for As(V). It was concluded that Chinese sugar cane straw is a cheap and effective biosorbent that can effectively be used for removal of roxarson, As(III) and As(V) ions from water [12].

CONCLUSION

Based on previous researches, it can be concluded that depending on the type of plant material, the optimal conditions of biosorption varies a lot. The initial characteristics of plants (porousness, the presence of functional groups) are significant and determine the later behavior of the biosorbent during biosorption. Also, chemical modifications of biosorbents can increase available adsorption sites by increasing surface area, pores and number of metal binding functional groups. Most of the papers are based on synthetically prepared heavy metal solutions with only one metal ion. Using plant materials, as low-cost biosorbent, has proven to be very effective for removing heavy metals from water. Future research should continue to identify additional low-cost materials that are effective at removing heavy metals.

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