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Mining and Metallurgy
Institute Bor

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Ljubiša Balanović
Dejan Tanikić

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PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the **56th International October Conference on Mining and Metallurgy (IOC 2025)**, scheduled to take place at **Bor Lake, Serbia**, from **October 22nd to 25th, 2025**.

The collaborative efforts of the University of Belgrade – Technical Faculty in Bor and the Mining and Metallurgy Institute Bor have once again brought together academia, industry, and research institutions to organize this year's IOC. Our focus remains firmly set on presenting the latest research achievements and technological advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines.

This year's conference program is rich and diverse, featuring **4 plenary lectures, 4 invited lectures, 158 full papers, and 6 abstracts**. The proceedings reflect the contributions of authors from **19 countries**: Austria, Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Hungary, India, Mexico, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, Turkey, and the United Kingdom. Among the submitted papers, eight young researchers under the age of 35 have qualified to participate in the "**MDPI Young Researcher Award**" competition, further emphasizing the conference's commitment to supporting and recognizing excellence among the new generation of scientists and engineers.

We are also delighted to host the **9th International Student Conference on Technical Sciences (ISC 2025)**, running in parallel with IOC 2025. The student conference brings together young researchers from Serbia and the wider region, with **one plenary** and **50 student papers** presented, offering an invaluable opportunity for the next generation of scientists and engineers to share their ideas and discuss the future of their disciplines with experts. The "**Professor Dragana Živković Best Student Paper Award**" will be presented to the most outstanding student contribution based on originality, research quality, and presentation.

The Organizing Committee expresses its deepest gratitude to all who have supported this event. Our General Sponsor is the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia. We are especially grateful to our Platinum Donors, HBIS Serbia and Serbia Zijin Mining, as well as our Gold Sponsor, DPM Metals Inc., and our Gold Donors, Copper Mill Sevojno and Serbia Zijin Copper Bor. This year, the conference is also supported by the Silver Donor, "MC LABOR" d.o.o. Beograd.

We proudly host a diverse exhibition, featuring Indemak, Labtim SE d.o.o., MERIS d.o.o., Krug International LTD, Altium International d.o.o., Metalurg Foundry Ltd., Fugro Germany Land GmbH, Analysis d.o.o., Lola institut, Tescan and Mikrolux d.o.o., Trokuttest Serbia, Novos d.o.o., Changsha Rui Rui Technology Co., Ltd., and the Winery of Bukovo Monastery. The official opening of the conference has been supported by Epiroc Srbija a.d.. Finally, we warmly acknowledge our Friends of the Conference: Messer Tehnogas AD Belgrade, the China-Serbia Joint Laboratory on Green Steel Manufacturing, and the Foundation B.Sc. Eng. Boško Injac.

We sincerely thank all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions to shaping IOC 2025. We are confident that the conference will once again serve as a alive platform for scientific exchange, professional networking, and the promotion of sustainable development in mining, metallurgy, and related fields.

On behalf of the 56th IOC Organizing Committee,
Prof. dr Ljubiša Balanović

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Abstracts

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Original scientific paper

STATISTICAL MODELING OF COPPER IONS BIOSORPTION ONTO SUNFLOWER HULLS

Miljan Marković[1a], Milan Gorgievski[1b], Marina Marković[1c], Vesna Grekulović[1d], Nada Štrbac[1e], Kristina Božinović[1f], Milica Zdravković[1g]

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Abstract

The statistical modeling of the copper ions biosorption onto sunflower hulls is presented in this work. The analysis was conducted using the Response Surface Methodology coupled with the Box-Behnken Design. The software experimental design, consisting of 17 experiments, was applied to optimize the biosorption process. The obtained results indicated that the used model is statistically significant, and that the optimal conditions for copper ions biosorption onto sunflower hulls are: 0.7 g sunflower hull sample mass, 0.1 g dm^{-3} initial copper ions concentration, and pH of the solution 5. The analysis indicated that all three analyzed parameters are significant model terms.

***Keywords**: Response surface methodology; Box-Behnken design, biosorption, sunflower hull*

1. INTRODUCTION

In recent years, rapid industry growth accelerated the discharge of large amounts of pollutants into the surface and groundwater. Wastewater polluted with heavy metals is a serious worldwide environmental issue. Heavy metals are non-degradable pollutants, that tend to accumulate in living organisms, and cause a wide array of diseases and disorders. These pollutants are present in discharges from various industries, including metal processing, mining, surface treatment of metals, energy sector, etc. [1,2].

As a trace element, it is essential in living organisms as it participates in the synthesis of different types of enzymes. However, in bigger concentrations it is toxic to living organisms, as it affects the metabolism, cell growth, and other processes [3].

On the industrial scale, many technologies have been used to treat wastewater and remove toxic pollutants, including electrodialysis, chemical precipitation, adsorption, chemical precipitation, membrane separation, and others. These technologies come with several limitations and difficulties, that include high operating costs, high reagent usage, sludge production, high energy requirements, and inefficiency when it comes to low heavy metal concentrations [1,2].

Biosorption, i.e. the adsorpton of toxic pollutants using biological materials as adsorbents (biosorbents) has become a popular alternative method to conventional technologies. Biosorbents are economically and environmentally friendly, and have shown, to some extent, selectivity towards heavy metals, and can be used in a wide range of physico-chemical conditions [2].

2. EXPERIMENTAL

The sunflower hulls were ground and then sieved through a set of laboratory sieves, and the fraction (-1+0.4) mm was used for the Cu^{2+} biosorption experiments. The experiments were performed using synthetic copper solutions prepared using $CuSO_4 \cdot 5H_2O$ (p.a. purity). The pH value of the solutions was adjusted with 0.1 M KOH, and 0.1 M HNO_3. The chemicals used were manufactured by LACHEMA (Czech Republic).

The RSM-BBD experimental design, which was used to optimize the biosorption process, consisted of 17 experiments. The design was applied comparing three selected factors: biosorbent mass (A), initial copper ion concentration (B), and pH value of the solution (C). The test series and their values are listed in Table 1.

Table 1. Experimental ranges and their levels

Factors	Range level		
	-1	0	1
A – biosorbent mass, g	0.3	0.5	0.7
B – initial copper ion concentration, g dm^{-3}	0.1	0.2	0.3
C – pH of the solution	3	4	5

3. RESULTS AND DISCUSSION

The biosorption process was optimized using Response Surface Methodology (RSM) coupled with the Box-Behnken Design (BBD). The process optimization experimental design, given in Table 1, was applied to optimize the copper biosorption process onto sunflower hulls. The matrix of the experimental design, and the obtained results (response R – biosorption degree) are shown in Table 2.

Table 2. Experimental ranges and their levels

Run	A – biosorbent mass, g	B – initial copper ion concentration, g dm^{-3}	C – pH of the solution	R – biosorption degree, %
1	0	1	1	24.036
2	0	-1	-1	52.564
3	0	1	-1	15.433
4	-1	0	-1	11.726
5	1	0	-1	18.613
6	0	-1	1	75.396
7	0	0	0	40.007
8	-1	-1	0	64.556
9	0	0	0	30.026
10	0	0	0	32.221
11	-1	0	1	27.351
12	-1	1	0	15.537
13	1	-1	0	74.086
14	1	1	0	35.557
15	1	0	1	45.475
16	0	0	0	32.377
17	0	0	0	35.348

A polynomial equation (1) was fitted in order to describe the correlation between the independent variables: linear (β_1, β_2, β_3), quadratic (β_{11}, β_{22}, β_{33}), interaction terms (β_{12}, β_{13}, β_{23}) and the response (R) [4]:

$$R = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 C + \beta_{11} AA + \beta_{22} BB + \beta_{33} CC + \beta_{12} AB + \beta_{13} AC + \beta_{23} BC \quad (1)$$

The results obtained are shown in Table 2. The copper ions biosorption onto sunflower hulls can be expressed as:

$$R = 33.99 + 6.82A - 22.01B + 9.24C + 2.62A \cdot B + 2.81A \cdot C - 3.56B \cdot C - 1.31A^2 + 14.75B^2 - 6.89C^2 \quad (2)$$

The ANOVA statistical analysis was performed to determine the statistical significance of the applied model. The obtained results are given in Table 3. The significance of the individual coefficients is analyzed by the F-values and p-values. The coefficient is more significant as the F-value is higher and p-value lower. p-values below 0.0500 indicate a highly significant regression at a confidence level of 95 % [5,6].

Table 3. ANOVA analysis for the Response Surface model for copper ions biosorption onto sunflower hulls

Source	Sum of squares	df	Mean square	F-value	p-value	
Model	6116.00	9	679.56	61.42	< 0.0001	significant
A-A	372.11	1	372.11	33.63	0.0007	
B-B	3873.72	1	3873.72	350.12	< 0.0001	
C-C	683.06	1	683.06	61.74	0.0001	
AB	27.51	1	27.51	2.49	0.1588	
AC	31.57	1	31.57	2.85	0.1350	
BC	50.62	1	50.62	4.57	0.0697	
A^2	7.27	1	7.27	0.6570	0.4443	
B^2	916.31	1	916.31	82.82	< 0.0001	
C^2	199.92	1	199.92	18.07	0.0038	
Residual	77.45	7	11.06			
Lack of Fit	17.95	3	5.98	0.4024	0.7598	not significant
Pure Error	59.49	4	14.87			
Cor Total	6193.44	16				

The obtained F- and p-values (61.42 and < 0.0001) indicate that the model is significant, with further indication that there is only a 0.01% chance that this F-value appeared due to noise. The model fit was also confirmed by the regression coefficients of the predicted and experimental values (R^2 = 0.940 and adj-R^2 = 0.971).

P-values above 0.1000 indicate that the analyzed model terms aren't significant. In this case, A-A, B-B, C-C, BC, B^2 and C^2 are significant model terms.

The plot of actual vs predicted responses (shown on Figure 1) can also give insight into the significance of the applied model [6]. The obtained results show a good agreement between the experimental and the model predicted responses.

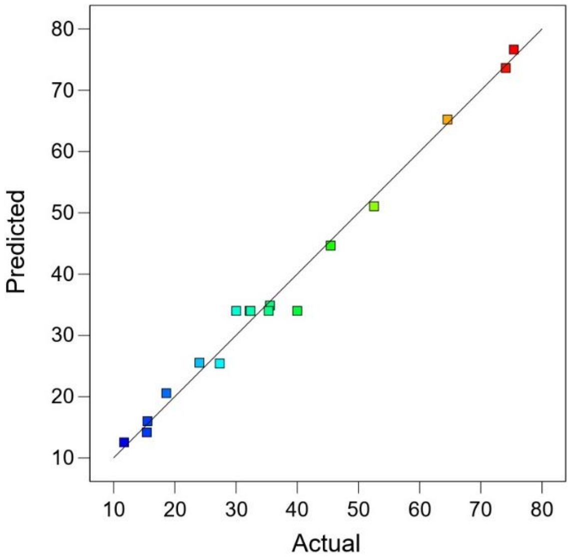

Figure 1. Actual vs model predicted responses

3D surface plots, illustrating the influence of the analyzed parameters on the system response (R) are shown on Figure 2.

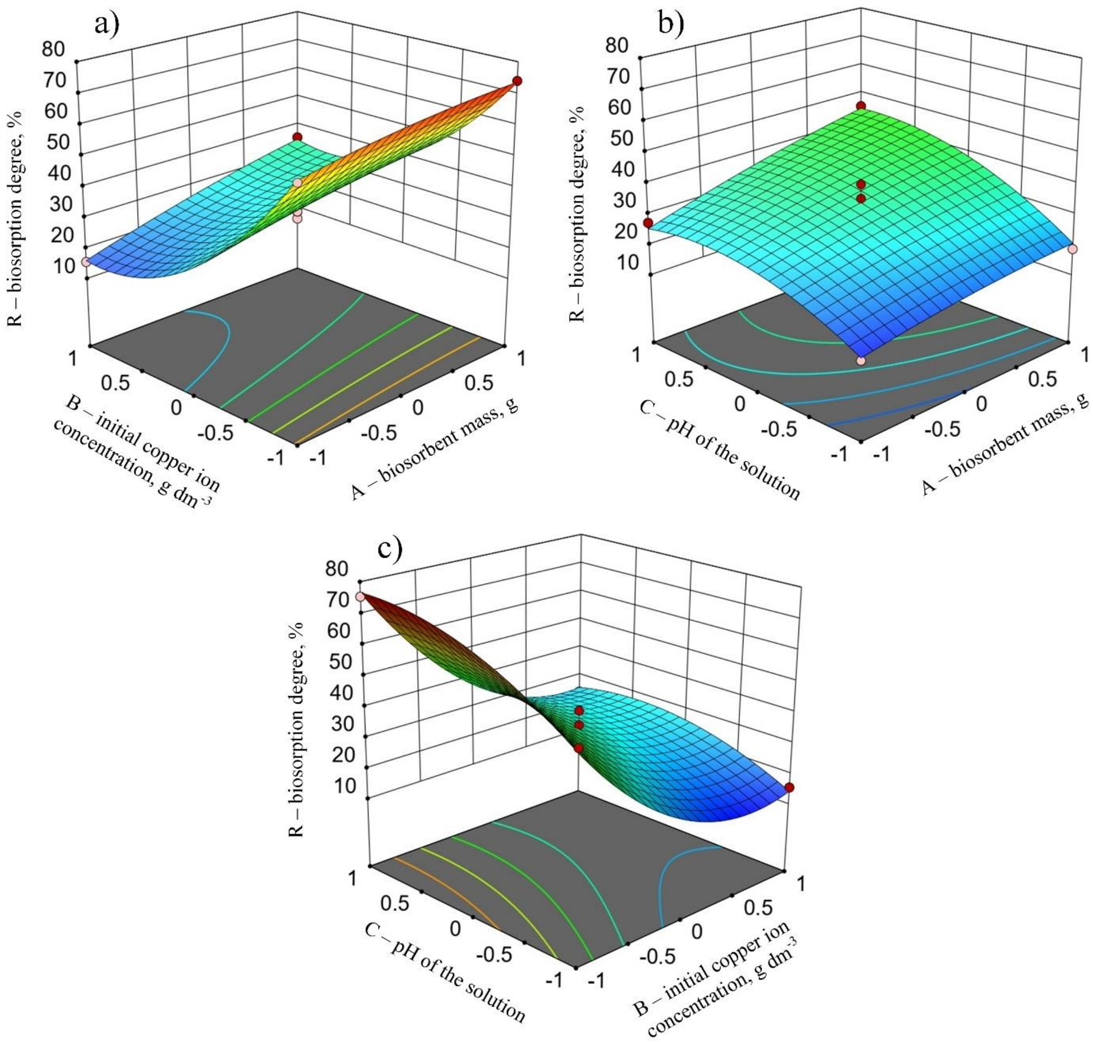

Figure 2. Response surface plots showing the interaction and influence on the biosorption rate (R) of (a) biosorbent mass (A) and initial copper ions concentration (B); (b) biosorbent mass (A) and pH of the solution (C); (c) initial copper ions concentration (B) and pH of the solution (C)

Figure 2a indicates that low initial copper concentrations in combination with high biosorbent mass led to a high response (biosorption degree). The interaction between the biosorbent mass and pH of the solution is shown on Figure 2b. It can be seen that higher biosorbent mass along with higher pH value of the solution led to a higher response, i.e. biosorption degree. Figure 2c (interaction between initial copper concentration and pH of the solution) indicated that lower initial copper concentrations in combination with higher pH values of the solution gave higher system responses, i.e. higher biosorption degree.

4. CONCLUSIONS

The optimization of the copper ions biosorption onto sunflower hulls was performed using the RSM-BBD method. The influence of three process parameters, i.e. the mass of the biosorbent, the initial copper ion concentration, and the pH of the solution was evaluated. The used model was determined to be statistically significant. The performed analysis suggested that the optimal conditions for copper ions biosorption onto sunflower hulls are: 0.7 g biosorbent mass, 0.1 g dm^{-3} initial copper concentration, and pH of the solution 5.

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