

University of Belgrade
Technical Faculty in Bor
Mining and Metallurgy
Institute Bor



56th International
October Conference
on Mining and Metallurgy
PROCEEDINGS

Editors:

Ljubiša Balanović

Dejan Tanikić



22-25 October 2025,
Bor Lake, Serbia

University of Belgrade
Technical Faculty in Bor
Mining and Metallurgy
Institute Bor



56th International
October Conference
on Mining and Metallurgy
PROCEEDINGS

Editors:

Ljubiša Balanović

Dejan Tanikić



22-25 October 2025,
Bor Lake, Serbia

**PROCEEDINGS,
56th INTERNATIONAL OCTOBER CONFERENCE
on Mining and Metallurgy**

Editors:

Prof. dr Ljubiša Balanović

Prof. dr Dejan Tanikić

University of Belgrade - Technical Faculty in Bor

Technical Editors:

MSc Miljan Marković

MSc Kristina Božinović

University of Belgrade - Technical Faculty in Bor

Proceedings cover design:

MSc Aleksandar Cvetković,

University of Belgrade - Technical Faculty in Bor

Publisher: University of Belgrade - Technical Faculty in Bor

For the publisher: Dean Prof. dr Dejan Tanikić

Circulation: 200 copies

Publication Place, Year: Bor, 2025

Printed by “*GRAFIKA GALEB DOO*” NIŠ, 2025

CIP - Каталогизacija у публикацији Народна библиотека Србије, Београд

622(082)(0.034.2)

669(082)(0.034.2)

**INTERNATIONAL October Conference on Mining and Metallurgy (56 ; 2025 ;
Bor Lake)**

Proceedings [Elektronski izvor] / 56th International October Conference on Mining and Metallurgy - IOC 2025, 22-25 October, 2025, Bor Lake, Serbia ; [organized by] University of Belgrade, Technical Faculty in Bor and Mining and Metallurgy Institute Bor ; editors Ljubiša Balanović, Dejan Tanikić. - Bor : University of Belgrade, Technical Faculty, 2025 (Niš : Grafika Galeb). - 1 USB fleš memorija ; 1 x 1 x 5 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 200. - Preface / Ljubiša Balanović. - Bibliografija uz svaki rad.

ISBN 978-86-6305-164-5

a) Рударство -- Зборници b) Металургија -- Зборници

COBISS.SR-ID 177493257

Bor Lake, Serbia, October 22-25, 2025



The conference is financially supported by
The Ministry of Science, Technological
Development and Innovation
of the Republic of Serbia

Platinum Donors

HBIS SERBIA



Gold Sponsor



Gold Donors



Silver Donor



Exhibitions



KRUG INTERNATIONAL LTD.



Donor of official opening



Friends of the Conference



**CHINA-SERBIA
JOINT LABORATORY
ON GREEN STEEL
MANUFACTURING**

HBIS and University of Belgrade



**THE FOUNDATION
'B.SC. ENG. BOŠKO INJAC'**

SCIENTIFIC COMMITTEE

Prof. Dr Dejan Tanikić, University of Belgrade, Technical Faculty in Bor (Serbia) - president
Prof. Dr Nada Štrbac, University of Belgrade, Technical Faculty in Bor (Serbia) - vice-president
Prof. Dr Radoje Pantović, University of Belgrade, Technical Faculty in Bor (Serbia) - vice-president
Dr Ana Kostov, Mining and Metallurgy Institute Bor (Serbia) - vice-president

Prof. Dr Milan Antonijević, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Hasan Avdušinović, University of Zenica, Faculty of Engineering and Natural Sciences (Bosnia and Herzegovina)
Dr Ana Alil, University of Belgrade, Institute of Chemistry, Technology and Metallurgy (Serbia)
Prof. Dr Ljubiša Balanović, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Farzet Bikić, University of Zenica, Faculty of Engineering and Natural Sciences (Bosnia and Herzegovina)
Prof. Dr Grozdanka Bogdanović, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Pavel Broz, Masaryk University, Faculty of Science, Department of Chemistry (Czech Republic)
Dr Mile Bugarin, Mining and Metallurgy Institute Bor (Serbia)
Prof. Dr Ilhan Bušatlić, University of Zenica, Faculty of Engineering and Natural Sciences (Bosnia and Herzegovina)
Prof. Dr Nicanor Cimpoesu, Gheorghe Asachi Technical University from Iasi (Romania)
Prof. Dr Mira Cocić, University of Belgrade, Technical Faculty in Bor (Serbia)
Dr Vladan Čosović, University of Belgrade, Institute of Chemistry, Technology and Metallurgy (Serbia)
Prof. Dr Pasquale D. Cavaliere, University of Salento, Department of Innovation Engineering (Italy)
Prof. Dr Kemal Delijić, University of Montenegro, Faculty of Metallurgy and Technology (Montenegro)
Prof. Dr Nikhil Dhawan, Indian Institute of Technology, Department of Metallurgical and Materials Engineering (India)
Prof. Dr Savas Dilibal, Istanbul Gedik University, Department of Mechatronics Engineering (Turkey)
Prof. Dr Aleksandar Dimitrov, Ss. Cyril and Methodius University in Skopje, Faculty of Technology and Metallurgy (Republic of North Macedonia)
Prof. Dr Natalija Dolić, University of Zagreb, Faculty of Metallurgy (Croatia)
Prof. Dr Yong Du, Central South University Changsha (China)
Prof. Dr Luis Filipe Malheiros, University of Porto, Faculty of Engineering (Portugal)
Prof. Dr Almajda Gigović-Gekić, University of Zenica, Faculty of Engineering and Natural Sciences (Bosnia and Herzegovina)
Prof. Dr Mirko Gojić, University of Zagreb, Faculty of Metallurgy (Croatia)
Prof. Dr Adam Grajcar, Silesian University of Technology, Department of Engineering Materials and Biomaterials (Poland)
Prof. Dr Vesna Grekulović, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Daniela Grigorova, University of Chemical Technology and Metallurgy, Faculty of Metallurgy and Material Science (Bulgaria)
Prof. Dr Stojan Groudev, University of Mining and Geology "Saint Ivan Rilski" (Bulgaria)
Prof. Dr Dragoslav Gusković, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Tomaš Havlik, Institute of Recycling Technologies, Faculty of Materials, Metallurgy and Recycling, Technical University of Kosice (Slovakia)
Prof. Dr Karl Heinz Spitzer, Technical University of Clausthal, Institute for Metallurgy (Germany)
Dr Slavomír Hredzák, Institute of Geotechnics of the Slovak Academy of Sciences (Slovakia)
Prof. Dr Svetlana Ivanov, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Dejan Ivezić, University of Belgrade, Faculty of Mining and Geology (Serbia)
Mirjam Jan-Blažič, Slovenian Foundry Society (Slovenia)
Prof. Dr Dominika Jendrzeczyk-Handzlik, AGH University of Science and Technology in Kraków, Faculty of Non-Ferrous Metals (Poland)
Prof. Dr Željko Kamberović, University of Belgrade, Faculty of Technology and Metallurgy (Serbia)
Prof. Dr György Kaptay, University of Miskolc, Faculty of Materials and Metallurgical Engineering (Hungary)
Dr Vladan Kašić, Institute for Technology of Nuclear and other Mineral Raw Materials (Serbia)

Prof. Dr Vladislav Kecojević, West Virginia University (USA)
Dr Dragan Komljenović, Research Institute, Hydro-Québec (Canada)
Prof. Dr Komnitsas Konstantinos, Technical University of Crete, School of Mineral Resources Engineering (Greece)
Prof. Dr Borut Kosec, University of Ljubljana, Faculty of Natural Science and Engineering (Slovenia)
Prof. Dr Maria Krasteva, University of Chemical Technology and Metallurgy, Faculty of Metallurgy and Material Science (Bulgaria)
Prof. Dr Vladimir Krstić, Functional Materials Manufacturing, Inc. (Canada)
Prof. Dr Stefan Kuvendžiev, Ss. Cyril and Methodius University in Skopje, Faculty of Technology and Metallurgy (Republic of North Macedonia)
Prof. Dr Silvia Lavrova-Popova, University of Chemical Technology and Metallurgy, Faculty of Chemical and Systems Engineering (Bulgaria)
Dr Milenko Ljubojev, Engineering Academy of Serbia (Serbia)
Prof. Dr Xuewei Lv, Chongqing University, School of Materials Science and Engineering (China)
Prof. Dr Nedeljko Magdalinović, Engineering Academy of Serbia (Serbia)
Prof. Dr Dragan Manasijević, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Vaso Manojlović, University of Belgrade, Faculty of Technology and Metallurgy (Serbia)
Prof. Dr Boštjan Markoli, University of Ljubljana, Faculty of Natural Science and Engineering (Slovenia)
Dr Branislav Marković, Institute for Technology of Nuclear and other Mineral Raw Materials (Serbia)
Prof. Dr Desimir Marković, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Ivana Marković, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Nobuyuki Masuda, Tokyo University of Science, Faculty of Advanced Engineering (Japan)
Prof. Dr Jožef Medved, University of Ljubljana, Faculty of Natural Science and Engineering (Slovenia)
Vladan Mihailović, Executive Director for Production at HBIS Serbia (Serbia)
Prof. Dr Ivan Mihajlović, Faculty of Mechanical Engineering, University of Belgrade (Serbia)
Dr Dragan Milanović, Mining and Metallurgy Institute Bor (Serbia)
Prof. Dr Snežana Milić, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Dragan Milovanović, University of Belgrade, Faculty of Mining and Geology (Serbia)
Prof. Dr Duško Minić, University of Priština, Faculty of Technical Sciences (Serbia)
Prof. Dr Srba Mladenović, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Adnan Mujkanović, University of Zenica, Faculty of Engineering and Natural Sciences (Bosnia and Herzegovina)
Prof. Dr Cornelia Muntean, Politehnica University of Timisoara (Romania)
Prof. Dr Tatiana N. Aleksandrova, Saint Petersburg Mining University, Department of Mineral Processing (Russia)
Prof. Dr Goran Načevski, Ss. Cyril and Methodius University in Skopje, Faculty of Technology and Metallurgy (Republic of North Macedonia)
Prof. Dr Adina Negrea, Politehnica University of Timisoara (Romania)
Prof. Dr Irena Nikolić, University of Montenegro, Faculty of Metallurgy and Technology (Montenegro)
Prof. Dr Đorđe Nikolić, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Daniel Ogochukwu Okanigbe, Tshwane University of Technology, Department of Extractive Metallurgy and Mineral Processing (South Africa)
Prof. Dr Dušan Oráč, Institute of Recycling and Environmental Technologies, Faculty of Materials, Metallurgy and Recycling, Technical University of Kosice (Slovakia)
Prof. Emeritus Dr. Sc. Mirsada Oruč, University of Zenica, Faculty of Engineering and Natural Sciences (Bosnia and Herzegovina)
Prof. Dr Dimitris Pnias, National Technical University of Athens, School of Mining Engineering and Metallurgy (Greece)
Prof. Dr Perica Paunović, Ss. Cyril and Methodius University in Skopje, Faculty of Technology and Metallurgy (Republic of North Macedonia)
Prof. Dr Mitar Perušić, University of East Sarajevo, Faculty of Technology Zvornik (Bosnia and Herzegovina)
Prof. Dr Batrić Pešić, University of Idaho, College of Engineering (USA)
Prof. Dr Marija Petrović Mihajlović, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Miljana Popović, University of Belgrade, Faculty of Technology and Metallurgy (Serbia)
Prof. Dr Milena Premović, University of Priština, Faculty of Technical Sciences (Serbia)
Prof. Dr Charikleia Prochaska, Aristotle University of Thessaloniki, Faculty of Sciences, School of Chemistry, Division of Chemical Technology and Industrial Chemistry (Greece)

Prof. Dr Miljana Radivojević, Institute of Archaeology, University College London (UK)
Prof. Dr Velimir Radmilović, Serbian Academy of Sciences and Arts (Serbia)
Prof. Dr Milan Radovanović, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Nenad Radović, University of Belgrade, Faculty of Technology and Metallurgy (Serbia)
Prof. Dr Žarko Radović, University of Montenegro, Faculty of Metallurgy and Technology (Montenegro)
Prof. Emeritus Karlo Raić, University of Belgrade, Faculty of Technology and Metallurgy (Serbia)
Prof. Dr Mirjana Rajčić Vujasinović, University of Belgrade, Technical Faculty in Bor (Serbia)
Dr Andrei Rotaru, University of Craiova, Department of Chemical Thermodynamics (Romania)
Prof. dr. eng. Elena Scutelnicu, "Dunarea de Jos" University of Galati, Faculty of Engineering (Romania)
Prof. Dr Snežana Šerbula, University of Belgrade, Technical Faculty in Bor (Serbia)
Dr Rustam Sharipov, JSC "Kazakh-British Technical University (Kazakhstan)
Dr Miroslav Sokić, Institute for Technology of Nuclear and other Mineral Raw Materials (Serbia)
Prof. Dr Jovica Sokolović, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Petr Solozhenkin, Russian Academy of Sciences (Russia)
Prof. Dr Dimitriu Sorin, Polytechnic University of Bucharest (Romania)
Dr Jasna Stajić Trošić, University of Belgrade, Institute of Chemistry, Technology and Metallurgy (Serbia)
Prof. Dr Velizar Stanković, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Rodoljub Stanojlović, University of Belgrade, Technical Faculty in Bor (Serbia)
Dr Jasmina Stevanović, University of Belgrade, Institute of Chemistry, Technology and Metallurgy (Serbia)
Dr Zoran Stevanović, Mining and Metallurgy Institute Bor (Serbia)
Prof. Dr Saša Stojadinović, University of Belgrade, Technical Faculty in Bor (Serbia)
Dr Srećko Stopić, RWTH Aachen University, Faculty of Georesources and Materials Engineering (Germany)
Prof. Dr Jasmin Suljagić, University of Tuzla, Faculty of Technology (Bosnia and Herzegovina)
Dr Zhongmei Sun, Zijin Mining and Metallurgy Research Institute (China)
Dr Nadežda Talijan, Academy of Engineering Science of Serbia (Serbia)
Prof. Dr Jarmila Trpčevská, Faculty of Materials, Metallurgy and Recycling, Technical University of Kosice (Slovakia)
Dr Biserka Trumić, Mining and Metallurgy Institute Bor (Serbia)
Prof. Dr Milan Trumić, University of Belgrade, Technical Faculty in Bor (Serbia)
Dr Walter Valery, University of Queensland (Australia)
Prof. Dr Dmitry Vasilyev, A.A.Baikov Institute of Metallurgy and Materials Science, Russian Academy of Sciences (Russia)
Prof. Dr Iveta Vaskova, Faculty of Materials, Metallurgy and Recycling, Technical University of Kosice (Slovakia)
Prof. Dr Petrica Vizureanu, Gheorghe Asachi Technical University from Iasi (Romania)
Prof. Dr Tatjana Volkov-Husović, University of Belgrade, Faculty of Technology and Metallurgy (Serbia)
Prof. Dr Maja Vončina, University of Ljubljana, Faculty of Natural Science and Engineering (Slovenia)
Prof. Dr Milovan Vuković, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Nenad Vušović, University of Belgrade, Technical Faculty in Bor (Serbia)
Prof. Dr Kaikun Wang, School of Materials Science and Engineering, University of Science and Technology Beijing (China)
Prof. Dr Ridvan Yamanoglu, Kocaeli University, Engineering Faculty, Metallurgical and Materials Engineering Department (Turkey)
Prof. Dr Onuralp Yucel, Istanbul Technical University, Faculty of Chemical and Metallurgical Engineering (Turkey)
Prof. Dr Zdenka Zovko Brodarac, University of Zagreb, Faculty of Metallurgy (Croatia)

ORGANIZING COMMITTEE

- Prof. Dr Ljubiša Balanović**, Full Professor (UB TF Bor) – president
Prof. Dr Radoje Pantović, Full Professor (UB TF Bor) – vice-president
Dr Ana Kostov, Principal Research Fellow (MMI Bor) – vice-president
- Dr Ivana Marković**, Full Professor (UB TF Bor)
- Prof. Dr Jovica Sokolović**, Full Professor (UB TF Bor)
- Dr Maja Nujkić**, Associate Professor (UB TF Bor)
- Dr Žaklina Tasić**, Associate Professor (UB TF Bor)
- Dr Milan Gorgievski**, Full Professor (UB TF Bor)
- Dr Ana Radojević**, Associate Professor (UB TF Bor)
- Dr Тања Калиновић**, Associate Professor (UB TF Bor)
- Dr Dejan Petrović**, Associate Professor (UB TF Bor)
- Dr Jelena Ivaz**, Associate Professor (UB TF Bor)
- Dr Anđelka Stojanović**, Associate Professor (UB TF Bor)
- Dr Uroš Stamenković**, Assistant Professor (UB TF Bor)
- Dr Jasmina Petrović**, Assistant Professor (UB TF Bor)
- Dr Vladimir Nikolić**, Assistant Professor (UB TF Bor)
- Milan Nedeljković**, Assistant (UB TF Bor)
- Milijana Mitrović**, Assistant (UB TF Bor)
- Marina Marković**, Assistant (UB TF Bor)
- Kristina Božinović**, Assistant (UB TF Bor)
- Milica Zdravković**, Assistant (UB TF Bor)
- Miljan Marković**, Assistant (UB TF Bor)
- Pavle Stojković**, Assistant (UB TF Bor)
- Avram Kovačević**, Assistant (UB TF Bor)
- Sandra Vasković**, English Lecturer (UB TF Bor)
- Oliver Marković**, IT service (UB TF Bor)
- Bojana Janković**, Accountant (UB TF Bor)

LIST OF REVIEWERS

- Prof. Dr Ridvan Yamanoglu, Kocaeli University (Turkey)
- Prof. Dr Peizhong Feng, School Materials Science and Physics, China University of Mining and Technology (China)
- Prof. Dr Srećko Stopić, IME Process Metallurgy and Metal Recycling, RWTH Aachen University (Germany)
- Prof. Dr Nebojša Tadić, University of Montenegro - Faculty of Metallurgy and Technology (Montenegro)
- Dr Aleksandra Mitovski, Engineering Dobersek GmbH (Germany)
- Prof. Dr Žarko Radović, University of Montenegro - Faculty of Metallurgy and Technology (Montenegro)
- Prof. Dr Ljubiša Balanović, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Milan Gorgievski, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Jan Vreštal, Masaryk University, Centre for Nanotechnology and Microtechnology (Czech Republic)
- Prof. Dr Claire Utton, University of Sheffield, Department of Materials Science and Engineering (UK)
- Prof. Dr Marija Petrović Mihajlović, University of Belgrade - Technical Faculty in Bor (Serbia)
- Doc. Dr Jelena Ivaz, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Radoje Pantović, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Miodrag Banješević, University of Belgrade - Technical Faculty in Bor (Serbia)
- Dr Danijel Kržanović, Mining and Metallurgy Institute Bor (Serbia)
- Dr Predrag Stolić, University of Belgrade - Technical Faculty in Bor (Serbia)
- Dr Vladan Marinković, Mining and Metallurgy Institute Bor (Serbia)
- Prof. Dr Saša Stojadinović, University of Belgrade - Technical Faculty in Bor (Serbia)
- Doc. Dr Ana Simonović, University of Belgrade - Technical Faculty in Bor (Serbia)
- Doc. Dr Dejan Petrović, University of Belgrade - Technical Faculty in Bor (Serbia)
- Dr Dragana Medić, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Milan Trumić, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Jovica Sokolović, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Ivana Marković, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Maja Trumić, University of Belgrade - Technical Faculty in Bor (Serbia)
- Dr Dejan Todorović, Institute for Technology of Nuclear and Other Minerel Raw Materials (Serbia)
- Prof. Dr Zoran Štirbanović, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Vesna Grekulović, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Dejan Tanikić, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Dominika Jendrzczyk-Handzlik, AGH University of Science and Technology in Kraków, Faculty of Non-Ferrous Metals (Poland)
- Prof. Dr Grozdanka Bogdanović, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Dragan Manasijević, University of Belgrade - Technical Faculty in Bor (Serbia)
- Prof. Dr Milan Radovanović, University of Belgrade - Technical Faculty in Bor (Serbia)

Dr Vesna Conić, Mining and Metallurgy Institute Bor (Serbia)
Dr Marija Korać, University of Belgrade - Faculty of Technology and Metallurgy (Serbia)
Dr Sanja Martinović, University of Belgrade - Institute of Chemistry, Technology and Metallurgy (Serbia)
Doc. Dr Uroš Stamenković, University of Belgrade - Technical Faculty in Bor (Serbia)
Dr Jasmina Petrović, University of Belgrade - Technical Faculty in Bor (Serbia)
Prof. Dr Srba Mladenović, University of Belgrade - Technical Faculty in Bor (Serbia)
Prof. Dr Saša Marjanović, University of Belgrade - Technical Faculty in Bor (Serbia)
Dr Viša Tasić, Mining and Metallurgy Institute Bor (Serbia)
Prof. Dr Junxue Zhao, School of Metallurgical Engineering, Xian University of Architecture and Technology (China)
Prof. Dr Miljana Radivojević, Institute of Archaeology, University College London (UK)
Prof. Dr Milena Premović Zečević, University of Priština, Faculty of Technical Science (Serbia)
Dr Ana Alil, University of Belgrade - Institute of Chemistry, Technology and Metallurgy (Serbia)
Prof. Dr Đorđe Nikolić, University of Belgrade - Technical Faculty in Bor (Serbia)
Prof. Dr Velimir Radmilović, University of Belgrade - Faculty of Technology and Metallurgy (Serbia)
Prof. Dr Tatjana Volkov-Husović, University of Belgrade - Faculty of Technology and Metallurgy (Serbia)
Prof. Dr Žaklina Tasić, University of Belgrade - Technical Faculty in Bor (Serbia)
Prof. Dr Tanja Kalinović, University of Belgrade - Technical Faculty in Bor (Serbia)
Dr Jelena Jordanovć, University of Belgrade - Technical Faculty in Bor (Serbia)
Prof. Dr Maja Nujkić, University of Belgrade - Technical Faculty in Bor (Serbia)
Prof. Dr Milica Veličković, University of Belgrade - Technical Faculty in Bor (Serbia)
Prof. Dr Snežana Milić, University of Belgrade - Technical Faculty in Bor (Serbia)
Dr Jelena Kalinović, University of Belgrade - Technical Faculty in Bor (Serbia)
Doc. Dr Ana Radojević, University of Belgrade - Technical Faculty in Bor (Serbia)
Dr Dragana Božić, Mining and Metallurgy Institute Bor (Serbia)
Prof. Dr Dejan Riznić, University of Belgrade - Technical Faculty in Bor (Serbia)
Dr Vaso Manojlović, University of Belgrade - Faculty of Technology and Metallurgy (Serbia)
Prof. Dr Predrag Đorđević, University of Belgrade - Technical Faculty in Bor (Serbia)
Dr Emina Požega, Mining and Metallurgy Institute Bor (Serbia)
Dr Vladan Ćosović, University of Belgrade, Institute of Chemistry, Technology and Metallurgy (Serbia)
Prof. Dr Duško Minić, University of Priština, Faculty of Technical Science (Serbia)

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., Trokutest 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

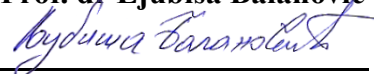


TABLE OF CONTENTS

Plenary Lectures

Markus A. Reuter (GERMANY)

Fundamental limits of green metal and mineral processing supply chains within the circular economy 3-5

Miljana Radivojević (UNITED KINGDOM)

Metals and the making of the ancient world: environmental and economic legacies of Eurasian bronze age metallurgy 6-6

Peizhong Feng, Baojing Zhang, Zhi Liu, Shiheng Li, Xiaohong Wang (CHINA)

Recycling and utilization of spent molybdenum disilicide: preparation of coating and metal recovery via synergistic smelting 7-9

Srećko Stopić, Alexander Birich, Bernd Friedrich (GERMANY)

Advances in understanding of reduction processes in extractive metallurgy 10-10

Invited Lectures

Buxin Chen, Mao Chen, Meilong Hu, Kaihui Ma, Hongqing Liu, Chenguang Bai (CHINA)

Development of hydrogen metallurgy in China 13-16

Alejandro Cruz-Ramírez, José Enrique Sanchez-Vite, Teresita del Refugio Jiménez-Romero, Margarita García-Hernández, Heriberto Mendoza-Cárdenas (MEXICO)

Characterization of industrial jarosites from the Mexican zinc extraction process 17-20

Nicanor Cimpoesu, Ionuț Adomniței, Corneliu Munteanu, Mihai Axinte, Marian Luțcanu, Mihai Alin Pop, Marius Teleşcă, Ana Maria Roman (ROMANIA)

Characterization of ceramic coatings with thermal barrier role obtained by atmospheric plasma jet spraying 21-24

Cemalettin Okay Aksoy, Güzin Gülsev Uyar Aksoy, Hasan Berker Sarisan (TURKEY)

Computational fluid dynamics analysis of ventilation strategies for mitigating geothermal gas leakage in subsurface infrastructure projects 25-28

Conference Papers

Geology and Mining

Zoran Marković, Milić Erić, Aleksandar Milićević, Rastko Jovanović, Nikola Živković, Ivan Lazović, Milica Jovčevski (SERBIA)
Optimization of the electrostatic precipitators in unit A1 of the Kostolac a thermal power plant 33-36

Stefano Utili, Dainius Jenkus, Akanksha Mishra, Filippo Bianchi, Riccardo Castellanza (UNITED KINGDOM)
Optimal pitwall design for open pit mines in the presence of faults 37-44

Katarina M. Mihajlović, Jovica Stojanovic, Slavica Mihajlović, Ivana Jelić, Ana S. Radosavljević-Mihajlović, Suzana Erić (SERBIA)
Comparative mineralogical analysis of two zeolitic tuff Slanci and Zlatokop 45-47

Edita Lazarová, Mária Bali Hudáková, Vít'azoslav Krúpa, Alexander Kiovský, Pavol Vavrek, Lucia Ivaničová (SLOVAKIA)
Results from experimental research of rock breaking by small diameter diamond core drill bits 48-51

Edita Lazarová, Vít'azoslav Krúpa, Pavol Vavrek, Mária Bali Hudáková, Lucia Ivaničová, Alexander Kiovský (SLOVAKIA)
Failure criterion of limestone and granodiorite determined by laboratory tests and theoretical processing of drilling process results 52-55

Mária Bali Hudáková, Edita Lazarová, Vít'azoslav Krúpa, Pavol Vavrek, Lucia Ivaničová, Alexander Kiovský (SLOVAKIA)
Optimisation of the rock drilling process conducted with small diameter drilling tools 56-59

Vladan Kašić, Ana Radosavljević-Mihajlović, Jovica Stojanović, Slavica Mihajlović, Nataša Đorđević, Ivana Jelić (SERBIA)
Geological and technological characteristics of the Igroš-Vidojevići zeolite tuff deposits 60-64

Marija Jonović, Dejan Bugarin, Tanja Stanković (SERBIA)
Sensitivity analysis of a copper ore exploitation investment project using COMFAR III software 65-68

Branimir Farkaš, Ana Hrastov, Iva Štefičar (CROATIA)
Factors influencing the occurrence of flyrock phenomena on surface mines-case study 69-72

Petar Radichev (BULGARIA)
Strategic planning, design and mine management under the conditions of the Asarel open pit mine 73-76

<u>Gergana Meracheva, Efrosima Zaneva-Dobranova, Nikolay Hristov</u> (BULGARIA) <i>Geological conditions of natural H₂ exploration on the Balkan peninsula for prosperity mapping</i>	77-80
<u>Güzin Gülsev Uyar Aksoy, Cemalettin Okay Aksoy, Ozan Savaş</u> (TURKEY) <i>Seismic intelligence in surface blasting: seisblast-promax as a next-generation design and optimization tool</i>	81-84
<u>Milenko Jovanović, Daniel Kržanović, Miroslava Maksimović, Vladan Marinković, Stefan Trujić, Miomir Mikić</u> (SERBIA) <i>The importance of geogrids for landfill security and environmental protection</i>	85-89
<u>Daniel Kržanović, Milenko Jovanović, Radmilo Rajković, Miljan Gomilanović, Miloš Stojanović</u> (SERBIA) <i>NPV based optimization of final pit contours in the cementacija mining complex</i>	90-93
<u>Ivica Vojinović, Dragan Šabaz, Miloš Stojanović</u> (SERBIA) <i>Implementation of the sublevel caving mining method in the T4 ore body at the Jama Bor underground mine</i>	94-97
<u>Miloš Stojanović, Ivica Vojinović, Dragan Šabaz</u> (SERBIA) <i>Application of neural networks for optimizing rock bolt system in underground mining</i>	98-101
<u>Ivica Vojinović, Miloš Stojanović, Dragan Šabaz</u> (SERBIA) <i>Technological innovations transforming the mining industry: a short review</i>	102-105
<u>Danka Kostadinović, Dušan Randelović, Zoran Marković</u> (SERBIA) <i>Implementation of ground-mounted and floating solar panels in mines</i>	106-109
<u>Milan Protić, Ana Bijelić, Miomir Raos, Marjan Popović</u> (SERBIA) <i>Kinetic modeling of oak wood thermal degradation using the distributed activation energy model (DAEM)</i>	110-114
<u>Dragan Šabaz, Ivica Vojinović, Miloš Stojanović</u> (SERBIA) <i>Monitoring techniques for subsidence induced by mining operations: a review</i>	115-118
<u>Vladan Marinković, Miroslava Maksimović, Milenko Jovanović, Željana Novaković, Anđela Maričić</u> (SERBIA) <i>Geological structure and genesis of Zn, Pb deposit Ribnik-Šuplja Stijena</i>	119-122
<u>Radmilo Rajković, Vladan Marinković, Daniel Kržanović, Miomir Mikić, Milenko Jovanović</u> (SERBIA) <i>The possibility of long-term exploitation of copper ore in ore bodies of the Majdanpek copper mine</i>	123-126
<u>Miomir Mikić, Ivana Mikić, Milica Mededović, Radmilo Rajković</u> (SERBIA) <i>The global impact of climate change on the mining sector</i>	127-131

<u>Miomir Mikić, Daniel Kržanović, Milenko Jovanović, Sandra Milutinović, Ivana Mikić (SERBIA)</u>	
<i>The impact of climate change on mining in serbia, an overview</i>	132-135
<u>Milan Grozdanović, Živana Jovanović Pešić, Jelena Đoković, Dejan Tanikić (SERBIA)</u>	
<i>Analysis of the energy potential of briquettes made from ground plum, date, and avocado pits</i>	136-139
<u>Milivoje Zlatić, Dejan Petrović, Jelena Ivaz, Mladen Radovanović, Milan Stajić (SERBIA)</u>	
<i>Selection of primary support system for the river Mali Pek tunnel</i>	140-143
<u>Snežana Ignjatović, Branislav Petrović (SERBIA)</u>	
<i>Applying electrical survey to detect the thickness of the Epikartst</i>	144-147
<u>Nikola Jovanović, Jelena Stefanović, Miloš Živanović, Zlatko Pavlović, Nikola Miljković, Jelena Đorđević, Nikola Lekić (SERBIA)</u>	
<i>Building information modeling (BIM) as a tool for enhancing technical solutions in mining design: A case study of the main process building in Brskovo, Montenegro</i>	148-152
<u>Samil Hoskan, Bayram Kahraman (TURKEY)</u>	
<i>Comparing the accuracy of Kriging and IDW interpolation for estimating a Cu-Zn deposit in Turkey</i>	153-156
<u>Nenad Vušović, Milica Vlahović (SERBIA)</u>	
<i>Challenges in mining subsidence engineering</i>	157-160
<u>Mineral Processing and Recycling</u>	
<u>Igor Zh. Bunin, Alexey N. Kochanov (RUSSIA)</u>	
<i>On the mechanism of selective disintegration of rocks under explosive and pulse-discharge impacts</i>	163-166
<u>Renguo Li, Lanjie Li, Heng Ji, Minglei Gao, Shiwei Wang (CHINA)</u>	
<i>Experimental study on pelletization of blended sea sand ores</i>	167-170
<u>Milić Erić, Zoran Marković, Aleksandar Milićević, Rastko Jovanović, Danka Kostadinović, Ivan Lazović, Milica Jovčevski (SERBIA)</u>	
<i>Experimental research of the lignite drying process in packed bed</i>	171-174
<u>Slavko Todić, Predrag Lazić (SERBIA)</u>	
<i>Investigation of the flotation potential of sulfideoxide ore from the Veliki Majdan deposit</i>	175-178
<u>Vladimir Nikolić, Milan Trumić (SERBIA)</u>	
<i>Refinement of the bond work index calculation method for finer samples</i>	179-182

Jose Enrique Sanchez-Vite, Alberto Hernandez-Casimiro, Teresita del Refugio Jiménez-Romero, Alejandro Cruz-Ramírez, Margarita García-Hernández
(MEXICO)

Mineralogical evolution in industrial jarosite through flux-assisted roasting 183-186

Albin Dobersek, Aleksandra Mitovski, Olga Mishina, Andrej Avrachov, Pavel Saltykov, Viktoriia Zhmurova, Alexandra Friesen, Theresa Schulz
(GERMANY)

Gold recovery from flotation tailings in copper metallurgy: A sustainable approach to resource valorization 187-190

Ivana Jovanović, Dragan Milanović, Vesna Conić, Miloš Janošević, Daniela Urošević, Mile Bugarin (SERBIA)

Chemical-mineralogical characterization of carbonate-clay type lithium ore 191-194

Jelena Đorđević, Jelena Stefanović, Sandra Guševac, Nevena Marković, Zoran Avramović, Nikola Jovanović, Nikola Lekić (SERBIA)

Effect of recycled asphalt (RAP) and copper slag (CS) as partial substitution of natural aggregate in asphalt mixtures 195-198

Artur Hubert, Felix Heinicke (GERMANY)

Transferring common HPGR application from copper to lithium ore 199-202

Venkateswara Rao, Jayapal Reddy (INDIA)

Mathematical modeling and statistical analysis of sub grade iron ore beneficiation using wet high intensity magnetic separator (WHIMS) 203-210

Dušica Mirović, Yuankun Yang, Shengli Yu (SERBIA)

Safety challenges in transport of copper concentrate: TML as a boundary parameter of maritime cargo stability 211-214

Klaudia Kundráková, Jana Pirošková, Jakub Klimko, Jarmila Trpčevská, Petra Růžičková, Dušan Oráč (SLOVAKIA)

Electrospinning of ZnO nanofibers from zinc galvanizing flue dust 215-220

Dragana Marilović, Grozdanka Bogdanović (SERBIA)

Leaching of covellite in ionic liquid solution 221-224

Nadezhda Kazakova, Vladislava Stefanova, Petar Iliev, Biserka Lucheva
(BULGARIA)

Analytical study of zinc recovery from spent solutions resulting after galvanization process 225-228

Katarina Balanović, Maja Trumić, Tamara Gavrilović (SERBIA)

Influence of hidden neuron number on the performance of ANN models applied to deinking flotation data 229-232

Extractive Metallurgy and Process Innovations

Teresita del Refugio Jiménez-Romero, José Enrique Sanchez-Vite, Alejandro Cruz-Ramírez, Margarita García-Hernández, Ángel de Jesús Morales-Ramírez (MEXICO)

Recovery of copper from a chalcopyrite ore using natural deep eutectic solvents (NADES) of choline chloride-urea as a leaching agent 235-238

Alexey M. Amdur, Sergei A. Fedorov (RUSSIA)

Droplet flotation in metallurgical melts 239-242

Yuchao Shi, Taibai Fu, Xinyi Zhang, Liang Zhang, Shiyi Wen, Yuling Liu, Yingbiao Peng, Jiangxing Wang, Ziqing Xie, Yong Du (CHINA)

Development of ICALPHAD software for phase diagram calculation and intelligent thermodynamic optimization 243-246

Vesna Grekulović, Milica Zdravković, Milan Gorgievski, Nada Štrbac, Miljan Marković, Marina Marković, Kristina Božinović (SERBIA)

Electrochemical behavior of copper in chloride medium in the presence of pine cone macerate 247-250

Ana Kostov, Aleksandra Milosavljević, Ivan Jovanović (SERBIA)

DTA thermodynamic behaviour of the ternary system Ga-Ge-Sb 251-254

Dimitrije Anđić, Aleksandar Jovanović, Nikola Vuković, Ivana Jelić, Mladen Bugarčić, Vaso Manojlović, Miroslav Sokić (SERBIA)

Innovative oxidative system for leaching of Fe²⁺ from sphalerite concentrate 255-259

Vanja Trifunović, Snežana Milić, Ljiljana Avramović, Dragana Božić, Zoran Avramović (SERBIA)

Behavior of zinc, calcium and iron in the two-stage leaching process of the EAF dust 260-263

Petar Petrov (BULGARIA)

Creation of sintering cup for laboratory sintering installation 264-268

Angel Iliev, Daniela Grigorova (BULGARIA)

Thermodynamic investigation of carbothermic reduction of electric arc furnace dust 269-272

Xiaohua Liu, Renhao Tian, Yang You, Zhixiong You, Xuwei Lv (CHINA)

Numerical simulation of temperature field in a rotary hearth furnace under infrared-assisted heating conditions 273-276

Sara Lukovac, Nebojša Tadić, Dijana Đurović, Irena Nikolić (MONTENEGRO)

S/S treatment for aluminium slag waste using fly ash-based geopolymers 277-280

Xing Han, Hongqiang Liu, Lanjie Li, Pengyang Li, Xiaolong Guo (CHINA)

The role of hydrogen based shaft furnaces in steel industry decarbonization 281-286

<u>Gvozden Jovanović, Dimitrije Andić, Danijela Smiljanjić, Dragana Randelović, Branislav Marković</u> (SERBIA) <i>Behavior of plant micronutrients (Fe, Cu) during combustion of contaminated Sorghum spp.</i>	287-290
<u>Igor Zlatković, Živko Đorović</u> (SERBIA) <i>Analysis of the new sinter line in HBIS Group Serbia and creating conditions for production improvement</i>	291-295
<u>Nebojša Tadić, Irena Nikolić, Nina Jovović, Dejana Dizdar, Vanja Asanović, Milena Tadić</u> (MONTENEGRO) <i>Valorization of fly ash and plastic waste using geopolymerization technology</i>	296-299
<u>Miloš Vuleta, Milodarka Žugić, Vladan Andrejić, Tamara Ristić</u> (SERBIA) <i>Industrial optimization of BOF steelmaking: increasing scrap ratio through hot metal parameter control</i>	300-303
<u>Aleksandra Milosavljević, Ana Kostov, Marijana Pavlov-Kagadejev</u> (SERBIA) <i>Artificial intelligence challenges in modern alloy design</i>	304-307
<u>Vesna Conić, Miloš Janosević, Dragan Milanović, Ivana Jovanović, Daniela Urošević, Mile Bugarin</u> (SERBIA) <i>Overview of methods for bor separation</i>	308-311
<u>Sandra Guševac, Nevena Marković, Jelena Đorđević, Jelena Stefanović</u> (SERBIA) <i>The possibility of using copper slag aggregate in concrete</i>	312-315
<u>Emine Savilgan, Patrick Zhang</u> (TURKEY) <i>Leaching behaviour of phosphogypsum with different acids</i>	316-318
<u>Duško Minić, Milena Zečević, Aleksandar Đorđević, Veljko Minić</u> (SERBIA) <i>Electrical resistivity of the Al-Bi-Ge ternary alloys</i>	319-322
<u>Velizar Stanković, Miljan Marković, Milan Gorgievski, Stefan Đorđević</u> (SERBIA) <i>On the leachability of copper from copper-iron minerals mixture</i>	323-326
<u>Ferenc Kristaly, László Farkas, Andrea Mihalkó, Bence Tamás, Balázs Szeleczi</u> (HUNGARY) <i>Recoverable Pd and Pt accumulation in a Ca(OH)₂ based CO₂ filter of a hydrogenation organic byproduct plant</i>	327-330
<u>Oliver Dimitrijević, Ivana Jovanović, Vesna Conić, Dragan Milanović, Tanja Stanković</u> (SERBIA) <i>Example of dense media cyclone selection</i>	331-334

Petra Růžičková, Klaudia Kundráková, Kristína Talianová, Jakub Klimko, Dušan Oráč (SLOVAKIA)

Selective recovery of copper from hydrometallurgical processing of e-waste 335-340

Alloys, Composites, and Advanced Materials

Anca Cazac, Diana-Petronela Burduhos-Nergis, Andrei Victor Sandu, Mihai Popa, Costica Bejinariu (ROMANIA)

Strontium phosphate conversion coatings: A short review 343-346

Maja Vončina, Jožef Medved, Tinkara Smolar, Matej Steinacher (SLOVENIA)

Influence of heat treatments on mechanical properties of aluminium alloy EN AW-2011 347-350

Alexandra Tamara Sutic, Gheorghe Bădărău, Romeu Chelariu, Ramona Cimpoesu, Ana-Maria Roman, Mihai-Adrian Bernevig, Nicanor Cimpoesu (ROMANIA)

An assessment of corrosive and mechanical performance of biodegradable ZnMgTi alloys 351-354

Jožef Medved, Tilen Balaško, Stanislav Kores, Maja Vončina (SLOVENIA)

In-situ synthesis of Mg₂Si-reinforced amc 355-359

Karlo T. Raić, Mile B. Đurđević, Srećko Manasijević, Aleksandra Patarić, Marija Mihailović (SERBIA)

Statistical evolution of non-metallic inclusions in continuous cast Al-killed steel 360-363

Kristina Božinović, Dragan Manasijević, Ljubiša Balanović, Milan Gorgievski, Uroš Stamenković, Miljan Marković (SERBIA)

Microstructural analysis and thermal properties of Ag-Sn alloys 364-370

Srdan Matijašević, Mirko Grubišić, Nataša Đorđević, Ana Radosavljević-Mihajlović, Slavica Mihajlović (SERBIA)

The effect of the free energy change on crystallization in lithium-germanate glass 371-374

Jovana Ružić, Jelena Stašić, Marko Simić, Andrijana Žekić, Branislava Vučetić, Dušan Božić (SERBIA)

Influence of the heat treatment on the structural parameters of the CuCrZr-TiB₂ alloy 375-377

Ionuț Adomnitei, Daniela Lucia Chicet, Bogdan Istrate, Marcelin Benchea, Gheorghe Bădărău, Nicanor Cimpoesu (ROMANIA)

Obtaining and characterization of high yttria content in zirconia coatings 378-381

Florin Sorin Todirică, Daniela Lucia Chicet, Dragoș-Cristian Achiței, Vasile Manole, Mihai-Adrian Bernevig, Ioan Stîrbu, Nicanor Cimpoesu (ROMANIA)

Using energy dispersive spectroscopy for a stainless steel-brass welding interface characterization 382-385

Shehret Tilvaldyev, América Yamile Amaya Diaz, Adrian Alberto Castro De La Cruz (CANADA)

Analysis of the variations of the wing lift coefficient of unmanned aerial vehicles with increasing Reynolds number of airflow

386-389

Nebojša Tadić, Žarko Radović (MONTENEGRO)

Investigation of the influence of residual stresses on the mechanical properties of aluminum alloy strips

390-393

Aida Imamović, Mirsada Oruč, Milenko Rimac, Gorazd Kosec, Safet Hamedović (BOSNIA AND HERZEGOVINA)

Influence of dimensional size of rolled product made of S690QL steel on impact toughness and grain size

394-400

Krzysztof Pancikiewicz, Mariusz Maslak, Paulina Zajdel, Marcin Klimek (POLAND)

Phase transformations in a welded joint of unalloyed steel after long-term subcritical annealing

401-404

Franjo Kozina, Zdenka Zovko Brodarac, Ivica Buljeta, Natalija Dolić (CROATIA)

Analysis of crack formation in AlSi11 alloy automotive rim

405-408

Žaklina Tasić, Marija Petrović Mihajlović, Ana Simonović, Milan Radovanović, Milan Antonijević (SERBIA)

Carbon-based electrochemical sensor modified with metal oxide nanoparticles

409-412

Almaida Gigović-Gekić, Elvis Agović, Hasan Avdušinović, Branka Muminović (BOSNIA AND HERZEGOVINA)

Testing the impact of toughness of the welded joint of steel S21800

413-416

Lovro Liverić, Tamara Holjevac Grgurić, Marko Kršulja, Matej Fonović (CROATIA)

TEM Investigation of Cu-10Al-7Ag Shape Memory Alloy in As-Cast State

417-420

Marko Kršulja, Damir Karabaić, Lovro Liverić, Samir Grudić (CROATIA)

Comparison of non-destructive and destructive welding assessment tests on MAG-welded AISI316L and DH36 steels using K-309LT filler

421-425

Dana Bolibruchová, Martina Sýkorová, Marek Matejka (SLOVAKIA)

Influence of Be addition on mechanical and physical properties of alloys with low Si content

426-429

Milan Nedeljković, Srba Mladenović, Vladan Čosović, Ivana Marković, Jasmina Petrović, Uroš Stamenković, Milijana Mitrović, Avram Kovačević (SERBIA)

Microstructures and wettability behavior of Sn-0.7Cu solder doped with graphene nanosheets

430-433

<u>Srba Mladenović, Nikola Marinković, Dragica Milojković, Jasmina Petrović, Milan Nedeljković (SERBIA)</u> <i>Structural characterization of welded joints of AlSiMg alloys</i>	434-437
<u>Martina Sýkorová, Dana Bolibruchová, Marek Matejka (SLOVAKIA)</u> <i>Development of the Al-Si alloy with niobium addition for gigacastings</i>	438-441
<u>Veljko Savić, Vladimir Topalović, Jelena Nikolić, Marija Došić, Milena Obradović, Danijela Smiljanić, Snežana Grujić (SERBIA)</u> <i>Insights into the glass network structure of coal fly ash-based glass</i>	442-445
<u>Uroš Stamenković, Ivana Marković, Dragan Manasijević, Milan Nedeljković (SERBIA)</u> <i>Termomechanical treatment of S275JR steel: impact on microstructure, hardness, and impact toughness</i>	446-449
<u>Milan Protić, Momir Prašević, Nikola Mišić, Mimir Raos, Viša Tasić (SERBIA)</u> <i>Flammability assessment of acoustic insulation materials using mass loss calorimetry</i>	450-453
<u>Marek Matejka, Dana Bolibruchová, Martina Sýkorová (SLOVAKIA)</u> <i>Analysis of selected properties of Al-Si-Cu based alloy with tungsten addition</i>	454-457
<u>Žarko Mišković, Radivoje Mitrović, Danilo Pejčić, Jovana Antić (SERBIA)</u> <i>Overview of installations and methodologies for conveyor idlers testing-developed at the Faculty of Mechanical Engineering at the University of Belgrade</i>	458-461
<u>Mile B. Đurđević, Srećko Manasijević, Aleksandra Patarić, Marija Mihailović, Karlo Raić (SERBIA)</u> <i>Role of magnesium in solidification feeding of hypoeutectic Al-Si5-Mg alloys</i>	462-465
<u>Jelena Gligorijević Sokolović, Jasmina Petrović, Emina Požega (SERBIA)</u> <i>Casting of bronze castings with thin walls using wax-paraffin models and CO₂ hardened sand molds</i>	466-469
<u>Shi Wenli, Tanja Marinković Stojanović, Aleksandar Djuga, Marko Radosavljević, Stefan Nešić (SERBIA)</u> <i>Metallurgical and process challenges in flash butt welding of different dimensions of micro-alloyed steel on continuous pickle line</i>	470-473
<u>Emina Međedović, Vanja Asanović, Milena Tadić, Jasmina Grbović Novaković, Irena Nikolić, Anđela Mitrović Rajić (MONTENEGRO)</u> <i>Structural changes in pyrophyllite induced by mechanochemical modification and zinc oxide doping</i>	474-477
<u>Biljana Zlatičanin, Branislav Radonjić (MONTENEGRO)</u> <i>Effect of copper content on phase formation and mechanical response of Al-Cu alloys</i>	478-481

<u>Biljana Zlatičanin, Branislav Radonjić</u> (MONTENEGRO) <i>Combined effect of cooling conditions and Mg content on the microstructure and properties of Al-15Cu alloys</i>	482-485
<u>Vladimir Glushchenkov</u> (RUSSIA) <i>Improvement in the technology of pouring copper plates for their further use in electrolysis production</i>	486-489
<u>Marko Pavlović, Marina Dojčinović, Mirjana Stojanović</u> (SERBIA) <i>Cavitation resistance of talc-reinforced pyrophyllite ceramics</i>	490-493
<u>Salko Ćosić, Almir Osmanović, Jasmin Halilović</u> (BOSNIA AND HERZEGOVINA) <i>Probabilistic analysis of press fit joint load carrying capacity</i>	494-497
<u>Saša Marjanović, Milijana Mitrović, Emina Požega, Dragana Božić</u> (SERBIA) <i>Influence of cold rolling and annealing on the hardness of Cu-Al bimetallic strip</i>	498-501
<u>Emina Požega, Slavko Bernik, Dragana Božić, Srđana Magdalinović, Miloš Đukić, Jelena Gligorijević Sokolović, Radmilo Rajković</u> (SERBIA) <i>Properties of Se doped Bi₂Te₃ based material: Part I</i>	502-505
<u>Nandita Gupta, Kamlesh Kumar Singh, Manoj Kumar, Himanshu Khandelwal</u> (INDIA) <i>A study of single piece ceramic shell core for geometrically complex investment casting</i>	506-510
<u>Veljko Minić, Jelena Miladinović, Miljana Popović, Milena Zečević, Aleksandar Đorđević</u> (SERBIA) <i>Experimental characterization of the Bi-Ge-Pb ternary alloys</i>	511-514
<u>Ondrej Kožej, Iveta Vasková, Ladislav Jankovčín</u> (SLOVAKIA) <i>Investigation of gas and shrinkage porosity in AlSi10Mg alloy gearbox castings manufactured by HPDC</i>	515-521
<u>Jasmina Petrović, Srba Mladenović, Uroš Stamenković, Milan Nedeljković, Milijana Mitrović</u> (SERBIA) <i>Effect of oxy-cutting on the microstructure and hardness of high-carbon steel</i>	522-525
<u>Ivana Marković, Uroš Stamenković, Dragan Manasijević, Ljubiša Balanović</u> (SERBIA) <i>Changes in hardness and microstructure during isothermal aging of nickel-aluminum bronze</i>	526-529
<u>Ferenc Kristaly, László Farkas, Andrea Mihalkó, Bence Tamás, Balázs Szelecski</u> (HUNGARY) <i>Microscale features of Pd-Pt aggregates resulted from aniline hydrogenation tar incinerating process</i>	530-533

Sandra Milutinović, Ljubiša Obradović, Sanja Petrović, Srđana Magdalinović, Ivana Mikić (SERBIA)
Reinforcements in composite materials 534-537

Milijana Mitrović, Saša Marjanović, Biserka Trumić, Milan Nedeljković, Jasmina Petrović, Uroš Stamenković (SERBIA)
Influence of temperature and annealing time on changes of the mechanical properties of the CuFe1 alloy 538-541

Zoran Karastojković, Radiša Perić, Srba Mladenović (SERBIA)
Limitations for wider usage of gold-aluminium alloys based on intermetallic compound Au-Al₂ 542-545

Dragan Jeremić, Željko Šutović, Milić Ječmenica, Dragomir Glišić, Stefan Dikić, Nenad Radović (SERBIA)
Development of 12.0mm thick hot rolled strip of S640MC grade steel in HBIS Serbia 546-549

Technology and Energy

Margarita García-Hernández, Alejandro Cruz-Ramírez, Ángel de Jesús Morales-Ramírez, José Enrique Sanchez-Vite, Teresita del Refugio Jiménez-Romero (MEXICO)
Decay time determination from luminescence emissions of Eu³⁺ doped Y₂O₃ powder 552-555

Valery Pierre Vassiliev, Cristopher Stanley (RUSSIA)
Optimization of heat capacities of sphalerite and wurtzite phases as a single system 556-559

Rastko Jovanović, Ivan Lazović, Milić Erić, Zoran Marković, Marija Živković (SERBIA)
Predicting CO emissions using novel numerical model for particle ignition/combustion 560-563

Marija Jeremić, Andreas Krammer, Markus Lehner (AUSTRIA)
Biomass to BioSNG-Methanation of syngas from biomass gasification 564-567

Duško Kostić, Mitar Perušić, Srećko Stopić, Dragan Kostic, Jelena Vuković, Nebojša Vasiljević, Radislav Filipović, Vladimir Damjanović (BOSNIA AND HERZEGOVINA)
High-pressure oxygen leaching of tironite residue for titanium recovery 568-574

Zoran Avramović, Dragana Božić, Vanja Trifunović, Jelena Stanković (SERBIA)
Cathodic protection of metals 575-578

Milica Zdravković, Slađana Savić, Vesna Grekulović, Dalibor Stanković, Iva Dimitrievska (SERBIA)
ATR-FTIR characterization of the white willow bark extract used as a copper corrosion inhibitor 579-582

Milica Zdravković, Edina Huseinović, Jasmina Dedić, Emir Horozić, Vesna Grekulović (SERBIA)

Extraction of bioactive compounds from nettle seeds as a potential inhibitor of metal corrosion

583-587

Milica Zdravković, Slađana Savić, Vesna Grekulović, Dalibor Stanković (SERBIA)

HPLC-DAD identification of compounds in corrosion inhibitor Salix Alba bark extract and the hydrolyte

588-592

Milos Đukić, Stefan Đordievski, Sanela Vasiljević, Dragana Adamović-Marković, Emina Požega, Jelena Nikolić, Vesna Stankov-Jovanović (SERBIA)

Internal quality control of ICP-MS method for water analysis

593-596

Environmental Protection, Remediation and Risk Assessment

Aleksandar Grigorov, Silviya Lavrova, Daniela Grigorova (BULGARIA)

Application of nanomaterials in water treatment from manganese

599-602

Ana Marinković, Jovana Buha Marković, Jasmina Savić, Milica Mladenović, Milić Erić, Zoran Marković, Biljana Vučićević (SERBIA)

Assessment of mercury content in different fuel types

603-606

Marija Koprivica, Marija Simić, Jelena Petrović, Jelena Dimitrijević, Marija Ercegović, Marija Marković (SERBIA)

Tree leaf biochar as a potential adsorbent for lead ion removal from aqueous solution

607-610

Vesna Krstić, Danijela Simonović, Renata Kovačević, Daniel Kržanović, Mirjana Šteharnek, Daniela Urošević, Sunčica Stanković (SERBIA)

Multivariate statistical evaluation of agricultural soil contamination near the city of Bor

611-615

Ana Petrović, Stefan Đordievski, Miloš Đukić, Emina Požega, Jelena Gligorijević Sokolović, Dragana Adamović-Marković (SERBIA)

Application of metal foams for the water purification process

616-619

Viša Tasić, Tatjana Apostolovski-Trujić, Renata Kovačević, Bojan Radović, Nevena Ristić (SERBIA)

State of air quality in the city of Bor in 2024

620-623

Aleksandra Papludis, Slađana Alagić, Snežana Milić, Dragana Medić, Jelena Nikolić, Snežana Jevtović, Ivana Zlatanović Đaić (SERBIA)

Distribution of PAHs in soils from Bor region, taken from the rooting zone of poison ivy

624-627

Žarko Radović, Nebojša Tadić (MONTENEGRO)

Effect of air oxygen enrichment on gaseous fuels combustion and GHG emission

628-631

<u>Maja Nujkić, Žaklina Tasić, Sonja Stanković, Dragana Medić (SERBIA)</u> <i>Optimizing cadmium ion adsorption: predictive modeling based on literature data</i>	632-635
<u>Miljan Marković, Milan Gorgievski, Marina Marković, Vesna Grekulović, Nada Štrbac, Kristina Božinović, Milica Zdravković (SERBIA)</u> <i>Statistical modeling of copper ions biosorption onto sunflower hulls</i>	636-640
<u>Miloš Stojanović, Nicoleta Sorina Nemes, Adina Negrea, Mihaela Ciopec, Ivan Svrkota, Daniel Kržanović, Igor Svrkota (SERBIA)</u> <i>Environmental sampling strategy for the Romania–Serbia border mining region</i>	641-644
<u>Danka Kostadinović, Milić Erić, Ivan Iazović (SERBIA)</u> <i>Application of waste materials in green roofs</i>	645-648
<u>Branislava Matić, Snežana Živković Perišić, Srđan Mančević (SERBIA)</u> <i>Use of AIRQ+ software in assessing the impact on health from exposure to particles in Bor, Serbia</i>	649-654
<u>Jelena Kalinović, Tanja Kalinović, Ana Radojević, Snežana Šerbula, Jelena Jordanović (SERBIA)</u> <i>Assessment of element accumulation efficiency in plant parts using biological factor analysis</i>	655-658
<u>Milan Gorgievski, Marina Marković, Miljan Marković, Vesna Grekulović, Nada Štrbac, Kristina Božinović, Milica Zdravković (SERBIA)</u> <i>Equilibrium and thermodynamic analysis of the adsorption of copper ions on sunflower hulls</i>	659-663
<u>Marina Marković, Milan Gorgievski, Miljan Marković, Vesna Grekulović, Nada Štrbac, Kristina Božinović, Milica Zdravković (SERBIA)</u> <i>Kinetic analysis of copper ions adsorption on sunflower hulls</i>	664-668
<u>Danijela Šimonović, Daniel Kržanović, Renata Kovačević, Daniela Urošević, Mirjana Šteharinik, Sunčica Stanković, Vesna Krstić (SERBIA)</u> <i>Assessment of heavy metal contamination of soil and the ecological risk based on national limit values and quantitative indices</i>	669-673
<u>Aleksandra Petrović, Stefan Đordjević, Bojan Radović, Renata Kovačević (SERBIA)</u> <i>Assesment of PAH and PCB concentrations in Bor River bed sediments affected by mining and metallurgy</i>	674-677
<u>Stefan Đordjević, Ana Radojević, Tanja Kalinović, Maja Nujkić, Jelena Kalinović, Jelena Jordanović, Renata Kovačević, Yasumasa Ogawa (SERBIA)</u> <i>Assessment of the copper availability by extraction of riverbed sediments from Eastern Serbia with 0.5 M HCl</i>	678-681

Miloš Đukić, Stefan Đordjević, Sanela Vasiljević, Dragana Adamović-Marković, Ana Petrović, Jelena Nikolić, Vesna Stankov-Jovanović (SERBIA)
Cerovo river-Annual monitoring of impact of the Cerovo open-pit mine 682-685

Emine Savilgan, Patrick Zhang (TURKEY)
A review on recovery of REEs and radioactive materials from phosphogypsum 686-688

Industrial Management, Digitalization and Quality Control

Yufei Wang, Xiaoyu Zheng, Xiangyang Ying, Qi Huang, Xiong Shuai, Changfa Du, Ya Li, Yingbiao Peng, Yuling Liu, Yong Du (CHINA)
Integrated computational material engineering practice paths by Changsha Ruirui Technology: From CALPHAD to phase field and crystal plastic finite element 691-694

Aleksandra Fedajev, Sanela Arsić (SERBIA)
Is mining and quarrying most efficient and profitable export sector in Serbia? Insights from a multi-criteria performance analysis 695-699

Predrag Stolić, Zoran Jovanović, Željko Mravik, Marko Jelić, Sonja Jovanović, Aleksandra Milosavljević (SERBIA)
The path to better education of engineers using open data-A practical example in the Republic of Serbia 700-703

Tatjana Volkov Husović, Ana Alil, Sanja Martinović (SERBIA)
NDT methods for monitoring degradation of refractory lining for blast furnace and converter 704-711

Maria Krasteva, Petar Raykov (BULGARIA)
Quality control in the production of vacuum pumps for the automotive industry 712-715

Andelka Stojanović, Isidora Milošević, Dragan Manasijević (SERBIA)
Intra- and extra-EU trade in recyclable metals: opportunities for industrial symbiosis 716-720

Marijana Pavlov-Kagadejev, Aleksandra Milosavljević (SERBIA)
Application of metaheuristic algorithms in metallurgical industry: A review of methods and applications 721-724

Abstracts

Eugeniu Martac, Christine Laskov, Katarzyna Staniewska (GERMANY)
Mining after mining: Real-time XRF-CPT for strategic resource estimation in tailings reprocessing 727-727

Tilen Balaško, Aleš Nagode, Jiehua Li, Jožef Medved, Maja Vončina (SLOVENIA)
The role of lanthanum addition in the microstructural evolution of an EN AW-7175 alloy during solution annealing 728-728

<u>Wei Su, Yi Xing, Yang Zheng, Rongrong Lei</u> (CHINA) <i>Construction and technological progress of a comprehensive carbon reduction system for CCUS in the steel industry</i>	729-729
<u>Stefan Trujić, Miroslav Popović, Milenko Jovanović, Katarina Milivojević, Boško Vuković</u> (SERBIA) <i>Geological investigations of the 'Povlatna zona' and 'Istočno polje' of the Gacko Coal Basin (BiH) for coal quality assessment and design of a beneficiation plant (2023–2025)</i>	730-730
<u>Roxana Hobjâlă, Nicolae Răzvan Mititelu, Ștefana Agop, Laurențiu Slătineanu, Diana Diaconu</u> (ROMANIA) <i>The contribution and application of polymeric materials in the metallurgical industry</i>	731-731
<u>Ștefana Agop, Bogdan-Ionut Dochita, Roxana Hobjâlă, Nicanor Cimpoeșu, Tiberiu Sutic</u> (ROMANIA) <i>The behavior description of CuZnAl shape memory alloys through the dynamics of multifractal complex systems</i>	732-732
Publishing partners	733-738
Donors	739-772
Author Index	773-780

ASSESSMENT OF THE COPPER AVAILABILITY BY EXTRACTION OF RIVERBED SEDIMENTS FROM EASTERN SERBIA WITH 0.5 M HCl

Stefan Đordjević^{1a}, Ana Radojević^{2a}, Tanja Kalinović^{2b}, Maja Nujkić^{2c},
Jelena Kalinović^{2d}, Jelena Jordanović^{2e}, Renata Kovačević^{1b}, Yasumasa Ogawa^{3a}

¹ Mining and Metallurgy Institute Bor, Alberta Ajnštajna 1, 19210 Bor, Serbia

² Technical Faculty in Bor, University of Belgrade, V.J. 12, 19210 Bor, Serbia

³ Graduate School of International Resource Sciences, Akita University, Akita City, Japan

^{1a} stefan.djordjevski@irmbor.co.rs, 0000-0003-1737-8766

^{2a} aradojevic@tfbor.bg.ac.rs, 0000-0003-3138-154X

^{2b} tkalinovic@tfbor.bg.ac.rs, 0000-0003-0161-0065

^{2c} mnujkic@tfbor.bg.ac.rs, 0000-0002-6110-5135

^{2d} jkalinovic@tfbor.bg.ac.rs, 0000-0003-0088-2683

^{2e} jjordanovic@tfbor.bg.ac.rs, 0000-0002-8145-640X

^{1b} renata.kovacevic@irmbor.co.rs, 0000-0003-4108-0855

^{3a} y_ogawa@gipc.akita-u.ac.jp, 0000-0002-4044-3880

Abstract

This study assessed copper contamination and availability in riverbed sediments from 181 locations in Eastern Serbia. The highest total Cu concentrations (up to 26,400 mg/kg) with HCl-extractable fractions up to 80% were recorded downstream of the confluence of Bela and Timok Rivers, where secondary, highly labile copper phases dominated. In contrast, 145 of 181 samples contained <50% 0.5 M HCl-extracted Cu, indicating limited mobility. The findings highlight the need to assess both metal concentrations and speciation to evaluate ecological risk and guide site-specific management.

Keywords: Copper, Riverbed sediments, Bioavailability, Extraction

1. INTRODUCTION

Mining and metallurgical activities in the Bor region have significantly polluted river water and sediments in Eastern Serbia with potentially toxic elements (PTEs). Repeated discharges of flotation tailings into local rivers have led to their accumulation on riverbeds and floodplains along the Bor, Krivelj, Bela, and Timok Rivers. These tailings are still visibly present even at the confluence of the Timok and Danube Rivers. Approximately 2,000 hectares of fertile floodplain land along the Timok River have been contaminated by these deposits. In addition to the direct deposition of tailings, metal precipitation from polluted river water has further contributed to sediment contamination throughout the river system [1,2].

Although total PTE concentrations in sediments are elevated, the bioavailability of these elements to plants remains uncertain. Sequential extraction methods, such as the BCR procedure, are commonly employed to evaluate the partitioning of PTEs among different geochemical fractions [3]. However, these procedures involve multiple steps, making them labor-intensive and less practical for routine assessments. As an alternative, single extraction using diluted HCl has been proposed as a simplified and effective approach for estimating the concentrations of labile PTE forms in sediments [4-7].

In this study, the total digestion and 0.5 M HCl extraction was performed on riverbed sediment samples from Eastern Serbia, collected from areas impacted by copper mining and processing. The main objective was to assess the availability of copper and to evaluate the spatial distribution of both total and 0.5 M HCl-extracted copper concentrations.

2. EXPERIMENTAL

Riverbed sediment samples were collected at 181 locations in Eastern Serbia during the 2015 and 2016 sampling campaigns using a scoop sampling method. An average sampling density of approximately one sample per 46 km² was achieved. The samples were transported to the laboratory in labeled plastic bags, air-dried at room temperature, and subsequently sieved. The fraction smaller than 180 µm was retained for chemical analysis and extraction.

The total concentration of copper in the sediment samples was determined by Actlabs (Canada) following total digestion and analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). To estimate the available fraction of copper, 0.5 g of each sediment sample was subjected to extraction with 10 mL of 0.5 M hydrochloric acid [4]. The suspensions were agitated on a mechanical shaker for 1 hour, then centrifuged at 3,000 rpm for 20 minutes to separate the extract from the solid residue. The supernatants were filtered through 0.45 µm cellulose acetate syringe filters to remove any particulate matter. The filtered extracts were analyzed for copper concentrations using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES), model SPECTRO CIROS VISION, at the Mining and Metallurgy Institute Bor. The percentages (%) of extracted Cu, were calculated based on the total and HCl-extracted Cu concentrations.

3. RESULTS AND DISCUSSION

Table 1 summarizes the statistical parameters for total copper concentrations, 0.5 M HCl-extractable copper, and the percentage of extractable copper in riverbed sediments from Eastern Serbia. The total copper concentrations ranged from 3.1 mg/kg to 26,400 mg/kg, with a median of 49.8 mg/kg and an average of 990 mg/kg, indicating a strong spatial variability influenced by mining and metallurgy-related inputs.

Table 1. Descriptive statistics data based on the total and 0.5 M HCl-extracted Cu concentrations

Parameter	Unit	Minimum	Median	Average	Maximum
Total conc. of Cu	mg/kg	3.1	49.8	990	26,400
HCL extracted Cu	mg/kg	1.2	16.8	404	20,660
HCL extracted Cu	% of total Cu	4.7	35.4	37	99.4

Figure 1 shows the geochemical maps of total copper concentration (mg/kg) and the percentage of 0.5 M HCl-extracted copper concentrations relative to the total copper content in river bed sediments. The highest total copper concentrations were recorded in sediments from the Bor and Bela Rivers, as well as in the Timok River downstream from its confluence with the Bela River. Elevated concentrations were also observed in the middle and lower reaches of the Timok River, as well as in the Krivelj and Pek Rivers.

Among the locations with the highest total copper concentrations, the sites along the Timok River after its confluence with the Bela River exhibited the highest percentage of 0.5 M HCl-extracted copper. The source of labile copper is likely the precipitated material in the sediment that was formed by the neutralization of acidic waters from the Bela River by the alkaline waters of the Timok River [2]. Precipitated copper(II) species – such as copper(II) hydroxide (Cu(OH)₂), copper(II) carbonate (CuCO₃), and copper ions adsorbed onto iron(III) oxyhydroxides – are known to be readily soluble in acidic conditions, such as those provided by the 0.5 M HCl extraction. As a result, copper in these sediments is considered labile and may be readily mobilized under changing environmental conditions, increasing its potential bioavailability to aquatic organisms and plants.

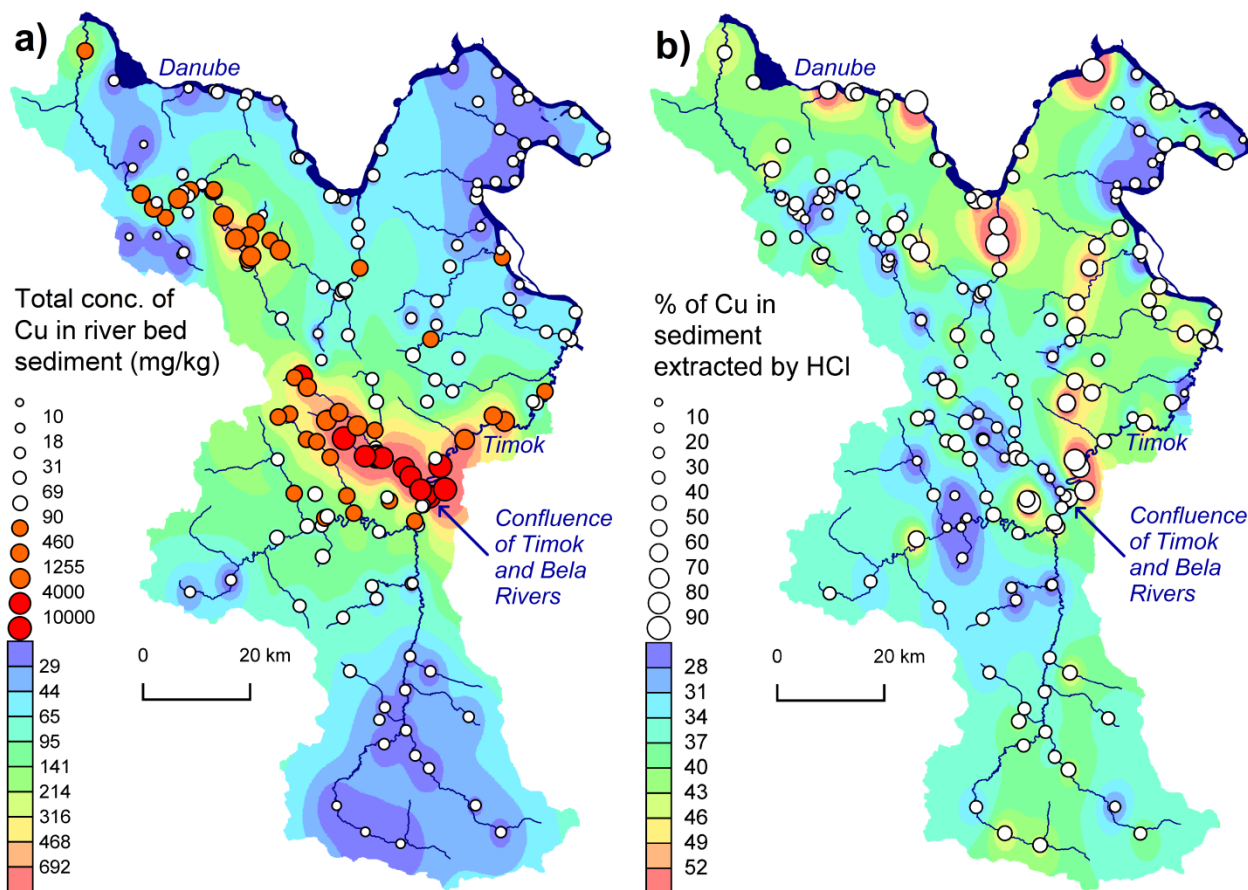


Figure 1. Geochemical maps of (a) total copper concentrations (mg/kg) and (b) the percentages of HCl-extracted copper relative to the total copper contents in river bed sediments

Figure 2 illustrates the relationship between total copper concentrations in riverbed sediments (blue bars, right y-axis) and the percentage of copper extracted using 0.5 M HCl (red line, left y-axis) for 181 sediment samples collected across Eastern Serbia. The samples are arranged in ascending order based on the percentage of 0.5 M HCl-extracted copper, enabling a direct comparison between the total copper content and its potentially available fraction.

A clear distinction is observed between samples in which copper is predominantly bound within stable mineral phases and those where it occurs in more labile, readily soluble forms. In 145 of 181 samples (~80% of samples), the percentage of 0.5 M HCl-extractable copper was below 50%, indicating that copper in the majority of samples was predominantly retained within relatively immobile mineral matrices. In contrast, two samples with the highest total copper concentrations (26,400 mg/kg and 16,300 mg/kg) also exhibited some of the highest percentages of 0.5 M HCl-extractable copper (78.3% and 79.3%, respectively). As discussed earlier, these locations are situated within 15 km downstream of the confluence of the Timok and Bela Rivers.

Some samples with relatively high total copper concentrations (5,000–15,000 mg/kg) but low extractable fractions (10–20%) still contain considerable amounts of labile copper (500–3,000 mg/kg), which may represent a potential ecological concern. The majority of these sediments were exposed to the acidic waters of the Bor and Bela Rivers, where the most mobile copper was likely already leached out. Conversely, 126 samples contained low total copper concentrations (<100 mg/kg), and although some of them exhibited relatively high percentages of mobile copper (up to 99.4%), the overall low copper content suggests that these locations are less likely to pose significant environmental risk despite the elevated copper availability.

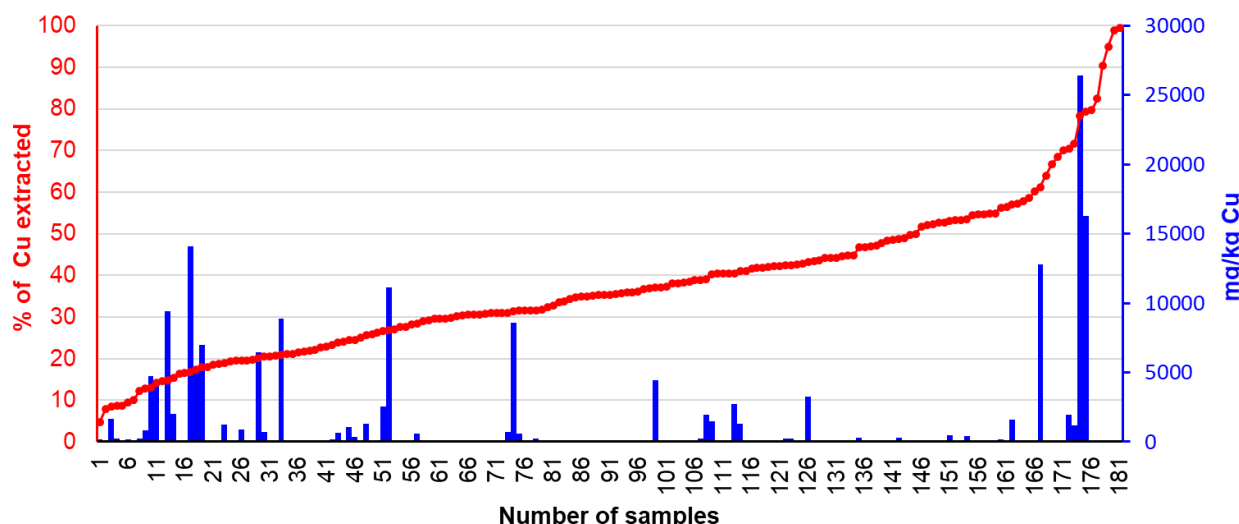


Figure 2. Total copper concentrations (blue bars) and percentages of HCl-extractable copper (red line)

4. CONCLUSION

This study demonstrates significant spatial variability in copper contamination and mobility within riverbed sediments of Eastern Serbia. While about 80% of samples contained less than 50% of 0.5 M HCl-extracted copper, indicating limited mobility, several pollution hotspots along the Timok River downstream of its confluence with the Bela River, exhibited extremely high total Cu concentrations (up to 26,400 mg/kg) combined with high extractable fractions (~80%). These locations were dominated by secondary, highly labile copper phases that can be readily mobilized under changing environmental conditions. The findings emphasize the need to assess both total metal concentrations and their chemical speciation when evaluating ecological risk and highlight the importance of site-specific management strategies.

ACKNOWLEDGEMENTS

This work was funded by the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia under contracts no. 451-03-136/2025-03/200052 (Mining and Metallurgy Institute Bor) and 451-03-137/2025-03/200131 (Technical Faculty in Bor). The data was obtained in scope of the E-cube project from the SATREPS program.

REFERENCES

- [1] S. Šerbula, V. Stanković, D. Živković, Ž. Kamberović, M. Gorgievski, T. Kalinović, *Mine Water Environ.* 35 (2016) 363-376.
- [2] S. Đordjević, D. Ishiyama, Y. Ogawa, Z. Stevanović, *Environ. Sci. Poll. Res.* 25 (2018) 25005-25019.
- [3] R. Kubota, A. Ohta, T. Okai, *Geochem. J.* 48 (2014) 165-188.
- [4] R. A. Sutherland, *Appl. Geochem.* 17 (2002) 353-365.
- [5] A. Cuvier, L. Leleyter, A. Probst, J.-L. Probst, J. Prunier, L. Pourcelot, G. Le Roux, M. Lemoine, M. Reinert, F. Baraud, *J. Geochem. Explor.* 225 (2021) 106762.
- [6] R. Devesa-Rey, F. Díaz-Fierros, M.T. Barral, *J. Environ. Manag.* 91 (2010) 2471-2477.
- [7] S.R. Giancoli Barreto, J. Nozaki, E. De Oliveira, V.F. Do Nascimento Filho, P.H.A. Aragão, I.S. Scarmínio, W.J. Barreto, *Talanta* 64 (2004) 345-354.