UNIVERSITY OF BELGRADE
Technical Faculty in Bor

PROCEEDINGS

32nd International Conference

Ecological Truth & Environmental Research

24-26 June 2026

Editor
Prof. Dr Ana Radojević

EcoTER'26

Hotel Sunce, Sokobanja, Serbia

UNIVERSITY OF BELGRADE
Technical Faculty in Bor

PROCEEDINGS

32nd International Conference

Ecological Truth & Environmental Research

24-26 June 2026

Editor
Prof. Dr Ana Radojević

EcoTER'26

Hotel Sunce, Sokobanja, Serbia

PROCEEDINGS

32nd INTERNATIONAL CONFERENCE

ECOLOGICAL TRUTH & ENVIRONMENTAL RESEARCH – EcoTER'26

Editor of the Proceedings:

Prof. Dr Ana Radojević, University of Belgrade – Technical Faculty in Bor

Technical Editors of the Proceedings:

Prof. Dr Tanja Kalinović, University of Belgrade – Technical Faculty in Bor

Ass. Prof. Dr Jelena Kalinović, University of Belgrade – Technical Faculty in Bor

Sonja Stanković, MSc, University of Belgrade – Technical Faculty in Bor

Editor of the 7th Student Section:

Prof. Dr Žaklina Tasić, University of Belgrade – Technical Faculty in Bor

Technical Editor of the 7th Student Section:

Anđelija Bogdanović, MSc, University of Belgrade – Technical Faculty in Bor

Publisher: University of Belgrade – Technical Faculty in Bor, Bor

For the publisher: Prof. Dr Dejan Tanikić, Dean

Printed: University of Belgrade – Technical Faculty in Bor, Bor, 100 copies, electronic edition

Year of publication: 2026

This work is available under the Creative Commons Attribution-Non-commercial-NoDerivs licence (CC BY-NC-ND)

CIP - Каталогизација у публикацији Народна библиотека Србије, Београд

502/504(082)(0.034.2)
574(082)(0.034.2)

INTERNATIONAL Conference Ecological Truth & Environmental Research (32 ; 2026 ; Sokobanja)

Proceedings [Elektronski izvor] / 32nd International conference Ecological Truth & Environmental Research - EcoTER'26, Sokobanja, Serbia, 24-26 June 2026 ;
[organized by] University of Belgrade, Technical faculty in Bor (Serbia) ; [co-organizers University of Banja Luka, Faculty of Technology – Banja Luka (B&H) ... [et al.]] ; [editor Ana Radojević]. - electronic ed. - Bor : University of Belgrade, Technical faculty in Bor, 2026 (Bor : University of Belgrade, Technical faculty in Bor). - 1 USB fleš memorija ; 1 x 2 x 4 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Preface / Ana Radojević. - Tiraž 100. - Bibliografija uz svaki rad.

ISBN 978-86-6305-171-3

a) Животна средина -- Зборници b) Екологија -- Зборници

COBISS.SR-ID 197972745

The 32nd International Conference
Ecological Truth & Environmental Research – EcoTER'26

is organized by:

UNIVERSITY OF BELGRADE
TECHNICAL FACULTY IN BOR
(SERBIA)

Co-organizers of the conference:

University of Banja Luka, Faculty of Technology, Banja Luka
(B&H)

University of Montenegro, Faculty of Technology, Podgorica
(Montenegro)

University of Zagreb, Faculty of Metallurgy, Sisak
(Croatia)

University of Pristina, Faculty of Technical Sciences, Kosovska Mitrovica
(Serbia)

Association of Young Researchers – Bor
(Serbia)

The EcoTER'26 conference is financially supported by

Republic of Serbia
MINISTRY OF SCIENCE,
TECHNOLOGICAL DEVELOPMENT AND INNOVATION

Platinum Donors of the EcoTER'26 conference

ZIJIN
SERBIA ZIJIN MINING

ZIJIN
SERBIA ZIJIN COPPER DOO

Gold Donors of the EcoTER'26 conference

HBIS SERBIA

ИНЖЕЊЕРСКА
КОМОРА
СРБИЈЕ

ElixirPrahovo

Silver Donor of the EcoTER'26 conference



Sponsor of Best Poster Awards

processes
an Open Access Journal by MDPI

Media Partnership with

applied sciences
an Open Access Journal by MDPI

SCIENTIFIC COMMITTEE

Prof. Dr Snežana Šerbula, University of Belgrade, Technical Faculty in Bor, Bor (Serbia), *President*
Prof. Dr Dejan Tanikić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)
Prof. Dr Milan Radovanović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)
Prof. Dr Snežana Milić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)
Prof. Dr Jovica Sokolović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)
Prof. Dr Đorđe Nikolić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)
Prof. Dr Yasumasa Ogawa, Faculty of International Resource Sciences, Akita University, Akita (Japan)
Prof. Dr Alok Mittal, Maulana Azad National Institute of Technology Bhopal, Bhopal (India)
Prof. Dr Markoli Boštjan, University of Ljubljana, Ljubljana (Slovenia)
Prof. Dr Jay Wadhawan, University of Hull, Hull (United Kingdom)
Prof. Dr Martin Brtnický, Mendelova univerzita v Brně, Brno (Czech Republic)
Prof. Dr Jan Bogaert, Liège Université (Gembloux Agro-Bio Tech), Liège (Belgium)
Prof. Dr Isabel Maria De Oliveira Abrantes, University of Coimbra (Portugal)
Prof. Dr Natalija Dolić, University of Zagreb, Faculty of Metallurgy, Sisak (Croatia)
Prof. Dr Shengguo Xue, Central South University, Changsha (China)
Dr Lidija Mančić, Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Belgrade (Serbia) / Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro (Brasil)
Prof. Dr Aleksandra Nadgórska-Socha, University of Silesia, Katowice (Poland)
Prof. Dr Bojan Marinković, Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro (Brasil)
Prof. Dr Milan D. Antonijević, University of Surrey, School of Chemistry & Chemical Engineering, Guildford (United Kingdom)
Prof. Dr Maurice Millet, Maison Interuniversitaire des Sci., Strasbourg (France)
Prof. Dr Murray T. Brown, University of Otago, Dunedin (New Zealand)
Prof. Dr Darko Vuksanović, University of Montenegro, Faculty of Metallurgy and Technology, Podgorica (Montenegro)
Prof. Dr Xiaosan Luo, Nanjing University of Information Science & Technology, Nanjing (China)
Prof. Dr Irena Nikolić, University of Montenegro, Faculty of Metallurgy and Technology, Podgorica (Montenegro)
Prof. Dr Daniel J. Bain, University of Pittsburgh, Pittsburgh (United States of America)
Dr Stefan Đorđievski, Mining and Metallurgy Institute Bor, Bor (Serbia)
Prof. Dr Tamara Rakić, University of Belgrade, Faculty of Biology, Belgrade (Serbia)
Prof. Dr Fernando Carrillo-Navarrete, Universitat Politècnica de Catalunya, Barcelona (Spain)
Prof. Dr Hyusein Yemendzhiev, "Prof. Dr. Assen Zlatarov" University, Burgas (Bulgaria)
Prof. Dr Polonca Trebše, University of Ljubljana, Faculty of Health Sciences, Ljubljana (Slovenia)
Dr Alena Bartonova, The Climate and Environmental Research Institute NILU, Kjeller (Norway)
Prof. Dr Adrian Eugen Cioablă, Politehnica University Timisoara, Faculty of Mechanical Engineering, Timisoara (Romania)
Prof. Dr George Z. Kyzas, International Hellenic University, Thermi (Greece)
Prof. Dr Nenad Stavretović, University of Belgrade, Faculty of Forestry, Belgrade (Serbia)
Prof. Dr Mustafa Imamoğlu, Sakarya Üniversitesi, Serdivan (Turkey)
Prof. Dr Milutin Milosavljević, Faculty of Technical Sciences, Kosovska Mitrovica (Serbia)
Prof. Dr Šefket Goletić, University of Zenica, Faculty of Mechanical Engineering, Zenica (B&H)
Dr Tanja Brdarić, University of Belgrade, Vinča Institute of Nuclear Sciences – National Institute of the Republic of Serbia, Belgrade (Serbia)
Prof. Dr Milovan Vuković, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Nada Blagojević, University of Montenegro, Faculty of Metallurgy and Technology, Podgorica (Montenegro)
Prof. Dr Džafer Dautbegović, University of Zenica, Faculty of Mechanical Engineering, Zenica (B&H)
Dr Jasmina Stevanović, University of Belgrade, Institute of Chemistry, Technology and Metallurgy, Belgrade (Serbia)
Dr Mirjana Marković, University of Belgrade, Vinča Institute of Nuclear Sciences – National Institute of the Republic of Serbia, Belgrade (Serbia)
Dr Ljiljana Avramović, Mining and Metallurgy Institute Bor, Bor (Serbia)
Prof. Dr Slavica Sladojević, University of Banja Luka, Faculty of Technology, Banja Luka (B&H)
Prof. Dr Popescu Francisc, Politehnica University Timisoara, Faculty of Mechanical Engineering, Timisoara (Romania)
Dr Dragana Ranđelović, Institute for Technology of Nuclear and Other Mineral Raw Materials, Belgrade (Serbia)
Prof. Dr Nada Šumatić, University of Banja Luka, Faculty of Forestry, Banja Luka (B&H)
Dr Viša Tasić, Mining and Metallurgy Institute Bor, Bor (Serbia)
Prof. Dr Milan Trumić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)
Prof. Dr Borislav Malinović, University of Banja Luka, Faculty of Technology, Banja Luka (B&H)
Prof. Dr Branimir Jovančićević, University of Belgrade, Faculty of Chemistry, Belgrade (Serbia)
Prof. Dr Tatjana Anđelković, University of Niš, Faculty of Sciences and Mathematics, Niš (Serbia)
Prof. Dr Jelena Mitrović, University of Niš, Faculty of Sciences and Mathematics, Niš (Serbia)

HONORARY COMMITTEE

Dr. Petar Paunović
(Zaječar, Serbia)

Prof. Dr Zvonimir Stanković
(Bor, Serbia)

Prof. Dr Velizar Stanković
(Bor, Serbia)

Prof. Dr Milan M. Antonijević
(Bor, Serbia)

Prof. Dr Ladislav Lazić
(Sisak, Croatia)

Dragan Ranđelović, Society of Young Researchers – Bor
(Bor, Serbia)

Toplica Marjanović, Society of Young Researchers – Bor
(Bor, Serbia)

Mihajlo Stanković, Special Nature Reserve of Zasavica
(Sremska Mitrovica, Serbia)

ORGANIZING COMMITTEE

Prof. Dr Ana Radojević, University of Belgrade, Technical Faculty in Bor, Bor (Serbia), *President*

Prof. Dr Tanja Kalinović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia), *Vice President*

Prof. Dr Marija Petrović Mihajlović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia), *Vice President*

Prof. Dr Maja Nujkić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Žaklina Tasić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Milica Veličković, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Ljubiša Balanović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Milan Gorgievski, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Jelena Šćepanović, University of Montenegro, Faculty of Metallurgy and Technology, Podgorica (Montenegro)

Prof. Dr Dejan Petrović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Asst. Prof. Dr Jelena Kalinović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Enisa Nikolić, English language teacher, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Sonja Stanković, MSc, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Anđelija Bogdanović, MSc, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Vladan Nedelkovski, MSc, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Aleksandar Cvetković, MSc, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Miljan Marković, MSc, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Oliver Marković, MSc, Tech Support, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Dragan Milenković, MSc, Tech Support, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

THE LIST OF REVIEWERS OF EcoTER'26

Dr Lidija Mančić, Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Belgrade (Serbia)/Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro (Brasil)

Dr Tanja Brdarić, University of Belgrade, Vinča Institute of Nuclear Sciences – National Institute of the Republic of Serbia, Belgrade (Serbia)

Prof. Dr Matej Fike, University of Maribor, Faculty of Energy Technology, Krško (Slovenia)

Dr Dragana Ranđelović, Institute for Technology of Nuclear and Other Mineral Raw Materials, Belgrade (Serbia)

Prof. Dr Grozdanka Bogdanović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Snežana Milić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Tamara Rakić, University of Belgrade, Faculty of Biology, Belgrade (Serbia)

Dr Dragana Adamović, Mining and Metallurgy Institute Bor, Bor (Serbia)

Prof. Dr Ivana Savić Gajić, University of Niš, Faculty of Technology, Leskovac (Serbia)

Dr Ljiljana Avramović, Mining and Metallurgy Institute Bor, Bor (Serbia)

Dr Mirjana Marković, University of Belgrade, Vinča Institute of Nuclear Sciences – National Institute of the Republic of Serbia, Belgrade (Serbia)

Dr Viša Tasić, Mining and Metallurgy Institute Bor, Bor (Serbia)

Dr Stefan Đorđievski, Mining and Metallurgy Institute Bor, Bor (Serbia)

Dr Dragana Božić, Mining and Metallurgy Institute Bor, Bor (Serbia)

Prof. Dr Jelena Mitrović, University of Niš, Faculty of Sciences and Mathematics, Niš (Serbia)

Prof. Dr Miloš Ilić, University of Novi Sad, Faculty of Sciences, Novi Sad (Serbia)

Prof. Dr Vesna Grekulović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Ivana Marković, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Ana Radojević, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Tanja Kalinović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Žaklina Tasić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Slađana Alagić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Ana Simonović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Milica Veličković, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Maja Nujkić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Milan Gorgievski, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Prof. Dr Ljubiša Balanović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Asst. Prof. Dr Jelena Kalinović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Asst. Prof. Dr Jelena Jordanović, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

Asst. Prof. Dr Vladimir Nikolić, University of Belgrade, Technical Faculty in Bor, Bor (Serbia)

PREFACE

The 32nd International Conference *Ecological Truth & Environmental Research – EcoTER'26* has been dedicated for more than three decades to presenting the latest scientific achievements, research findings, and innovative approaches in the fields of ecology, environmental protection, and sustainable development. In 2026, the conference was held in Sokobanja, Serbia, at Hotel Sunce, from 24 to 26 June.

The primary aim of the conference is to bring together leading experts, researchers, professionals, and young scientists from diverse fields in order to foster the exchange of knowledge, strengthen scientific collaboration, and promote innovative solutions to contemporary environmental challenges. By connecting science, education, industry, and society, EcoTER'26 seeks to inspire the transformation of attitudes and practices in everyday life, as well as within economic and industrial systems, contributing to a more sustainable future.

The 32nd International Conference *Ecological Truth & Environmental Research – EcoTER'26* is organized by the University of Belgrade, the Technical Faculty in Bor, with the co-organization of the University of Banja Luka, the Faculty of Technology; the University of Montenegro, the Faculty of Technology – Podgorica; the University of Zagreb, the Faculty of Metallurgy – Sisak; the University of Pristina, the Faculty of Technical Sciences – Kosovska Mitrovica; and the Association of Young Researchers – Bor (Serbia).

The Proceedings of EcoTER'26 include 98 scientific papers authored by researchers, academics, and industry representatives from universities, research institutions, and organizations across the following countries: Bosnia and Herzegovina, Bulgaria, the Czech Republic, Finland, Italy, Montenegro, North Macedonia, Pakistan, Romania, Slovenia, the Netherlands, the United Kingdom, the United States of America, Uzbekistan, and Serbia. It is our great honour and pleasure to welcome all participants and contributors and to express our sincere appreciation for their valuable scientific contributions.

Within this year's conference programme, the 7th Student Section – EcoTERS'26 was also organized. We highly value the contribution of students and their mentors, whose enthusiasm, creativity, and dedication represent an important foundation for the advancement of scientific knowledge. We encourage young researchers to continue exploring, questioning, and expanding the boundaries of knowledge, recognizing that education and scientific discovery are lifelong processes.

The support of our donors, together with their commitment, trust, and willingness to cooperate, has significantly contributed to the successful organization of the conference. The Organizing Committee expresses its deepest gratitude to the Platinum donors of the conference – Serbia Zijin Mining DOO Bor and Serbia Zijin Copper DOO Bor; the Gold donors – HBIS SERBIA, the Serbian Chamber of Engineers, and Elixir Prahovo; and the Silver donor – Rudex Explosives.

We extend our sincere appreciation to all authors who contributed to these Proceedings. Special recognition is given to the members of the Scientific, Organizing, and Honorary Committees, reviewers, invited speakers, session chairs, and all participants whose dedication and support have contributed to the success and continuity of EcoTER.

Our sincere gratitude goes to everyone who has contributed to the organization and delivery of this conference. Your efforts and collaboration continue to strengthen the mission of EcoTER and its role in promoting scientific excellence, environmental responsibility, and sustainable development.



Prof. Dr Ana Radojević

President of the Organizing Committee

TABLE OF CONTENTS

Plenary Lectures

Jay Wadhawan

DROPLET ELECTROCHEMISTRY: FROM LABORATORY TO INDUSTRIAL APPLICATIONS 1

Grozdanka Bogdanović

FROM WASTE TO RESOURCE: A SUSTAINABLE APPROACH TO LEACHING OF SULFIDIC TAILINGS 2

Invited Lectures

Vesna Vučurović

BIOETHANOL AS A RENEWABLE ENERGY SOURCE: EFFICIENCY, SUSTAINABILITY, AND ENVIRONMENTAL IMPACT 5

Bojana Bajić, D. Vučurović, S. Dodić

BIOPROCESS ENGINEERING FOR CIRCULAR BIOECONOMY: MODELLING, OPTIMIZATION AND VALORISATION OF AGRO-INDUSTRIAL RESIDUES AND WASTES 12

Ana Simonović

APPLICATION OF ENVIRONMENTALLY SAFE INHIBITORS FOR METAL CORROSION PROTECTION 18

Ivan Savić, I. Savić Gajić, T. Palanački Malešević, I. Mihalj Lubaščik, Z. Svirčev, J. Meriluoto

PAN-LIFE-CARPET CONCEPT: INTEGRATING WASTE VALORIZATION AND BIOCRUST ENGINEERING 22

Jovana Bezdan, A. Bezdan

NATURE-BASED SOLUTIONS UNDER CLIMATE CHANGE: AN OVERVIEW OF KEY FINDINGS FROM THE UNSFA PILOT SITE WITHIN THE DALIA AND SWIM PROJECTS 29

Conference Papers

Žarko Radović, N. Tadić

EFFECT OF AIR OXYGEN ENRICHMENT AND EXCESS AIR RATIO ON SOLID FUELS COMBUSTION 40

Nebojša Tadić, I. Nikolić, N. Jovović, A. Drakulović, V. Radmilović
STRENGTH AND MICROSTRUCTURE OF FLY ASH BASED GEOPOLYMERS CONTAINING WASTE PLASTIC 46

Aleksandra Papludis, S. Alagić, S. Milić, D. Medić, J. Nikolić, V. Stankov Jovanović, G. Stojanović
AN ASSESSMENT OF THE PRESENCE OF DIBENZ(a,h)ANTHRACENE, A PROBABLE HUMAN CARCINOGEN, IN THE BOR REGION, ON THE BASIS OF ITS CONTENT IN STEMS AND LEAVES OF COMMON IVY, LILAC, AND FIG 51

Aleksandar Cvetković, Ž. Tasić, M. Petrović Mihajlović, A. Simonović, M. Radovanović, A. Bogdanović, M. Antonijević, S. Stanković
ELECTROCHEMICAL SENSING OF CAFFEINE 57

Milutin Stojadinović, V. Marjanović, I. Svrkota
FUNDAMENTALS OF WASTE CHARACTERISATION SAMPLING ACCORDING TO CEN/TR 15310 63

Boris Novaković, N. Paskaš, Z. Stojanović, V. Lakušić, I. Živić
ENVIRONMENTAL VARIABLES AFFECT DISTRIBUTIONAL PATTERNS OF THE RIFFLE BEETLE (Coleoptera: Elmidae) SPECIES IN THE SERBIAN STREAMS AND RIVERS 71

Boris Novaković, J. Đuknić, N. Paskaš, M. Raković, V. Lakušić, I. Živić
RIFFLE BEETLE *Elmis maugetii* Latreille, 1802 (Coleoptera: Elmidae): NOTES ON THE SPECIES' MORPHOLOGICAL PLASTICITY IN THE BALKAN PENINSULA 78

Radenka Kolarov, Dj. Petrov, N. Galečić, D. Skočajić, J. Čukanović, S. Đorđević, M. Ocokoljić
CHALLENGES, LIMITATIONS AND KNOWLEDGE GAPS CONCERNING ALLOCHTHONOUS TREES IN URBAN ENVIRONMENTS: WINGED ELM 83

Radenka Kolarov, Dj. Petrov, N. Galečić, D. Skočajić, J. Čukanović, S. Đorđević, M. Ocokoljić
THE INFLUENCE OF THE URBAN HEAT ISLAND ON *Abelia* × *grandiflora* (ROVELLI EX ANDRÉ) REHDER TAXA 85

Radenka Kolarov, Dj. Petrov, N. Galečić, D. Skočajić, J. Čukanović, S. Đorđević, M. Ocokoljić
Pyracantha angustifolia (Franch.) C.K.SCHNEID. A NEW EXOTIC SPECIES IN THE DENDROFLORA OF BELGRADE 93

Milena Nikolić, A. Zdravković, D. Marković Nikolić, D. Stojadinović, T. Nikolić
EVALUATION OF ECOLOGICAL POTENTIAL OF VETERNICA RIVER BASED ON CHEMICAL QUALITY PARAMETERS 100

Vesna Obradović, M. Perović, T. Vučković
MICROBIOLOGICAL QUALITY OF THE VELIKA MORAVA RIVER: ECOLOGICAL AND PUBLIC HEALTH ASPECTS 106

Milan Đorđević, B. Stojanović, A. Zdravković, D. Stojadinović, T. Nikolić, Đ. Miltenović

ANALYSIS OF PHYSICAL HAZARDS IN THE ENVIRONMENT AND THEIR IMPACT ON HUMAN HEALTH: CASE STUDY OF THE CITY OF NIŠ, REPUBLIC OF SERBIA 112

Milan Đorđević, B. Stojanović, A. Zdravković, D. Stojadinović, T. Nikolić, M. Nikolić

IDENTIFICATION AND ANALYSIS OF NON-IONIZING ELECTROMAGNETIC RADIATION IN THE ENVIRONMENT: CASE STUDY OF LESKOVAC CITY, REPUBLIC OF SERBIA 119

Sanja Pavlović

COMBINED METEOROLOGICAL MEASUREMENTS OF URBAN AND RURAL THERMAL ENVIRONMENTS IN BELGRADE 126

Jovana Galjak, M. Krstić, S. Milojević, G. Milentijević

HEAVY METAL DISTRIBUTION AND CHEMICAL SPECIATION IN SOILS NEAR THE GORNJE POLJE FLOTATION TAILINGS 135

Ivana Kostić Kokić, D. Bogdanović, N. Stanković, T. Anđelković

AMMONIUM HYDROXIDE AND MILK FAT CONTENT EFFECT ON BENZYL BUTYL PHTHALATE EXTRACTION 142

Viša Tasić, V. Kamenović, B. Radović, R. Kovačević, N. Ristić, Z. Damnjanović, M. Cocić

INDOOR PM_{10} AND $PM_{2.5}$ IN RESIDENTIAL APARTMENTS IN BOR, SERBIA: NON-HEATING SEASON ANALYSIS 146

Biljana Budzakoska Gjoreska, S. Trajanovski, S. Trajanovska

INFLUENCE OF LITTORAL HABITAT CHARACTERISTICS ON MACROINVERTEBRATE COMMUNITIES IN LAKE OHRID 153

Vesna Marjanović, Z. Štirbanović, R. Marković

PLANNING AND IMPLEMENTATION OF MINING WASTE SAMPLING: STANDARDS AND LEGAL REGULATIONS 162

Miljan Vilimonović, J. Vesković, A. Okolišan, M. Vesković, M. Lučić, A. Onjia

MULTIVARIATE ASSESSMENT OF HEAVY METALS IN RIVER WATER FROM NOVI PAZAR AREA 169

Branislava Matić, V. Vukmanović, S. Živković Perišić

URBAN AIR QUALITY MEASURED CLOSE TO SCHOOLS AND KINDERGARTENS WITHIN THE LOCAL MONITORING NETWORK IN SERBIA 175

Tamara Mitić, A. Marić, K. Jovičić, V. Đikanović, N. Marinković, S. Anđus, J. Čanak Atlagić

UNCOVERING HIDDEN DIVERSITY OF *Sabanejewia balcanica* IN SERBIA: THE DISCOVERY OF NOVEL HAPLOTYPES 181

Olga Jakovljević, S. Popović, M. Pećić, D. Jerinkić
DIATOMS FROM LUDAŠ LAKE AND THEIR APPLICATION IN BIOINDICATION 187

Predrag Pajic, Ž. Rudic, N. Rakonjac
ASSESSMENT OF GROUNDWATER SUITABILITY FOR IRRIGATING URBAN GREEN SPACES IN ALLUVIAL AQUIFERS 194

Predrag Pajic, Ž. Rudic, N. Rakonjac
LONG-TERM PERSISTENCE OF FLUORIDE CONTAMINATION IN ALLUVIAL GROUNDWATER: A CASE STUDY OF THE CARINA WELLFIELD IN KLADOVO (SERBIA) 201

Željko Ćirović, D. Kleut, D. B. Stojanović, M. Jovašević-Stojanović
COMPARISON OF SATELLITE DATA WITH LOW-COST SENSOR NETWORK PM DATA IN FOUR CITIES IN SERBIA 210

Madalina Zot, F. Popescu
ASSESMENT OF SEDIMENTABLE PARTICULATE MATTER IN TIMISOARA 217

Ivana Kostić Kokić, N. Stanković, D. Bogdanović, T. Petronijević, M. Dudić, T. Anđelković
IMPACT OF DIMETHYL PHTHALATE ON THE GROWTH AND STRUCTURE OF CYANOBACTERIA (*Microcystis* sp.) 222

Ivana Kostić Kokić, N. Stanković, D. Bogdanović, T. Petronijević, M. Dudić, T. Anđelković
IMPACT OF DIMETHYL PHTHALATE ON THE GROWTH AND STRUCTURE OF GREEN ALGAE (*Chlorella* sp.) 228

Anđelija Bogdanović, Ž. Tasić, M. Petrović Mihajlović, A. Simonović, M. Radovanović, M. Antonijević, A. Cvetković
ELECTROCHEMICAL DETERMINATION OF CEFTRIAXONE USING A GRAPHITE ROD ELECTRODE 233

Milan Gorgievski, M. Marković, V. Grekulović, N. Štrbac, M. Marković, M. Zdravković, K. Božinović
SEM-EDS AND DTA-TGA ANALYSIS OF CORN STALKS USED FOR THE BIOSORPTION OF COPPER IONS FROM SYNTHETIC SOLUTIONS 239

Dubravka Nikolovski, S. Đurić, D. Mićić, G. Trajkovska, Lj. Lazić, T. Stajić, D. Stošić, K. Kralj, J. Zec
LONG-TERM TRENDS OF AIRBORNE POLLEN IN PANČEVO 243

Milena Nikolić, A. Zdravković, D. Marković Nikolić, G. Petković, T. Nikolić
REMOVAL OF SYNTHETIC DYE FROM AQAEOUS SOLUTIONS USING *Qercus cerris* ACORN CUPS 250

Milena Nikolić, A. Zdravković, D. Marković Nikolić, N. Ristić, I. Ristić
KINETIC AND THERMODYNAMIC ASPECTS OF PESTICIDE SORPTION ONTO HORSE CHESTNUT SEED SORBENT 256

Jovana Perendija, V. Ljubić, D. Milošević, S. Cvetković, M. Đuriš, Ž. Milovanović

COMPARATIVE KINETIC ANALYSIS OF CATIONIC DYES ADSORPTION ONTO SUSTAINABLE LIGNOCELLULOSIC BIOSORBENTS 261

Verica Ljubić, J. Perendija, D. Milošević, Ž. Milovanović, S. Cvetković, K. Trivunac

MECHANISMS AND FACTORS INFLUENCING Ni(II) BIOSORPTION BY BACTERIAL EXOPOLYSACCHARIDES: A REVIEW 266

Dunja Banđur, R. Prodanović, M. Spasojević Savković, M. Stanković, D. Bartolić, O. Prodanović, N. Surudžić

ENZYMATIC DEGRADATION OF PHENOL VIA HRP PERIODATELY IMMOBILIZED ONTO GMA-CO-EGDMA MACROPOROUS CARRIERS 273

Nena Velinov Georgiev, M. Radović Vučić, M. Petrović, M. Kostić, M. Momčilović, J. Mitrović, A. Bojić

SORPTION OF TEXTILE DYES ONTO BISMUTH-MODIFIED WOOD WASTE SORBENT: KINETIC AND EQUILIBRIUM ANALYSIS 279

Saša Rančev, M. Petrović, S. Najdanović, N. Velinov Georgiev, J. Mitrović, M. Radović Vučić, A. Bojić

SELF-MADE PULSATING ATMOSPHERIC PRESSURE CORONA PLASMA REACTOR FOR DEGRADATION OF A TEXTILE DYE IN SYNTHETIC TEXTILE EFFLUENT 284

Jelena Mitrović, N. Velinov Georgiev, M. Momčilović, M. Petrović, M. Kostić, S. Najdanović, A. Bojić

THERMALLY ACTIVATED PEROXYDISULFATE DEGRADATION OF REACTIVE TEXTILE DYES 290

Darko Anđelković, M. Branković

DIRECT INFUSION MS AS A PROMISING TOOL FOR PESTICIDES QUALITATIVE SCREENING IN APPLES 297

Darko Anđelković, M. Branković

CALIBRATION PERFORMANCES OF A MULTIRESIDUE PESTICIDES ANALYSIS IN LEMON AND LETTUCE ON QqQ AND ION TRAP MASS SPECTROMETERS 304

Darko Anđelković, M. Branković

THE NATURE OF THE MATRIX EFFECT IN GC/MS PESTICIDES ANALYSIS IN APPLES AND ITS RELATION TO EXTRACT DILUTION 310

Isidora Santrač, F. Sekereš, M. Živković, J. Korać Jačić, M. Milenković, J. Danilović Luković

DEGRADATION OF PONCEAU S DYE BY ADVANCED OXIDATION PROCESSES: COMPARATIVE ANALYSIS AND TOXICITY OF TRANSFORMATION PRODUCTS 316

Isidora Santrač, F. Sekereš, M. Živković, J. Korać Jačić, M. Milenković, J. Danilović Luković

BIOLOGICAL EFFECTS OF EVANS BLUE AND ITS DEGRADATION PRODUCTS ON GROWTH AND VIABILITY OF THE GREEN MICROALGA *Chlamydomonas ccidophila* PM01 324

Irina Vasić, I. Čeliković, A. Samolov, T. Milanović, A. Kandić, M. Đurašević

ANNUAL EFFECTIVE DOSE DUE TO INGESTION OF HERBAL INFUSIONS FROM ASTERACEAE MEDICINAL PLANTS 330

Dušan Nikolić, S. Marjanović, M. Dimitrijević, Z. Marković, A. Dobričić, M. Stanković, B. Rašković

CONCENTRATIONS OF METALS AND METALLOIDS IN MEAT OF THE COMMON CARP (*Cyprinus carpio*) FARMED USING FEED BASED ON INVERTEBRATE ANIMAL PROTEIN ORIGIN 336

Dunja Banđur, D. Bartolić, M. Stanković, M. Prokopijević, N. Surudžić, S. Stanković, M. Mićić

LABEL-FREE FLUORESCENCE-BASED OPTICAL BIOSENSOR FOR RAPID DETECTION OF FUNGAL PATHOGENS 343

Katarina Jovičić, V. Đikanović, J. S. Vranković

REDOX BIOMARKERS IN SEMINAL PLASMA OF CULTURED RAINBOW TROUT: TOS, TAS, AND OSI 348

Petar Petrov

UTILIZATION OF A PRODUCT FROM SULFURIC ACID PRODUCTION, POLLUTING THE ENVIRONMENT, WITH APPLICATION IN FERROUS METALLURGY 353

Despina Kostadinova Jankovski, M. Arizanova, B. Ristovski, E. Velickova, D. Doneva-Shapcheska

VALORIZATION OF BREWERY SPENT GRAIN INTO BIOPLASTIC FILMS: INFLUENCE OF BIOMASS LOADING ON BARRIER AND ANTIOXIDANT PROPERTIES 360

Boris Novaković, M. Raković

SOUTHEASTERN EUROPEAN BLACKBIRD *Turdus merula aterrimus* (MADARÁSZ, 1903) IN THE BALKAN PENINSULA 368

Pasquale Napoletano, E. Vitale, A. De Marco, C. Arena

PROPERTIES OF PLANT AND SOIL SHAPING FRUIT AND OIL TRAITS IN DIFFERENT CULTIVARS OF *Olea europaea* L. 374

Dragana Ranđelović, S. Valiyev, M. Nasirov, J. Amirov

GERMINATION OF *Artemisia diffusa* Krasch. ex. Poljakov SEEDS ORIGINATED FROM RANGELAND SITES OF DIFFERENT GRAZING INTENSITIES 381

Mihajlo Stanković, N. Beslac, D. Romčević

NEW FINDING SPECIES ABLEPHARUS KITAIBELII BIBRON & BORY, 1833 (*Reptilia: Squamata: Scincidae*) IN BOSNIA AND HERZEGOVINA 386

Mihajlo Stanković

CONTRIBUTION OF THE DISTRIBUTION OF THE SPECIES *Ricciocarpos natans* (L.) CORDA 1829 IN THE SNR ZASAVICA AND MAČVA WITH THE ANALYSIS OF THE HABITAT 394

Sonja Stanković, M. Radovanović, A. Simonović, Ž. Tasić, A. Cvetković, V. Nedelkovski, D. Medić

PROCESS OPTIMIZATION OF ZnO-ASSISTED PHOTOCATALYTIC DEGRADATION OF METHYL ORANGE USING RESPONSE SURFACE METHODOLOGY 403

Uroš Stamenković, I. Marković, D. Manasijević, K. Božinović, M. Nedeljković, A. Kovačević

CHARACTERIZATION OF THE Sn78Bi22 ALLOY AS AN ENVIRONMENTALLY FRIENDLY LEAD-FREE SOLDER 410

Miljan Marković, M. Gorgievski, V. Grekulović, N. Štrbac, M. Marković, K. Božinović, M. Zdravković

CHANGE IN METAL REMOVAL DEGREE DURING COPPER ION BIOSORPTION ONTO RAW AND CALCINED CHICKEN EGGSHELLS 417

Ivana Marković, U. Stamenković, M. Nedeljković, D. Manasijević, Lj. Balanović

ENVIRONMENTAL ASPECTS AND EXPERIMENTAL INVESTIGATION OF SAC/GNS COMPOSITE LEAD-FREE SOLDER 422

Katarina Stojanović, M. Simić, D. Aćimović, B. Savić Rosić, M. Ječmenica Dučić, T. Brdarić

THERMAL TRANSFORMATION OF NSAID-DERIVED MATERIALS: MORPHOLOGICAL AND COMPOSITIONAL INSIGHTS 427

Katarina Stojanović, M. Simić, D. Aćimović, B. Savić Rosić, M. Ječmenica Dučić, T. Brdarić

PRODUCTION COST ASSESSMENT OF SnO_2-MWCNT@SS ELECTRODE FOR WASTEWATER TREATMENT 432

Natalija Nedić, S. Bulatović, T. Tadić, B. Marković, A. Nastasović

AMBROSIA-BASED BIOSORBENTS FOR REMOVAL OF RHODAMINE B FROM AQUATIC SOLUTION 438

Ljubiša Balanović, U. Stamenković, I. Marković, K. Božinović, M. Gorgievski, V. Grekulović, T. Jogrić

EFFECT OF Ni AND Si ADDITIONS ON FUNCTIONAL PROPERTIES OF Cu-30Zn BRASS 443

Katarina Stojanović, M. Simić, D. Aćimović, B. Savić Rosić, M. Ječmenica Dučić, D. Maksin, T. Brdarić (SERBIA)

SYNERGISTIC INTERACTION BETWEEN Sb AND RARE-EARTH OXIDES IN SnO_2 ELECTROCATALYSTS 452

Milan Đorđević, B. Stojanović, A. Zdravković, D. Stojadinović, T. Nikolić, S. Stojanović
QUANTITATIVE DETERMINATION OF ESSENTIAL AND TOXIC ELEMENTS CONTENT IN PEACH FRUITS BY ICP-OES METHOD 456

Sofija Banković, M. Lj. Petrović, A. Janković, M. Rakin, M. Vukašinović Sekulić
ANTIOXIDANT ACTIVITY OF CLOVE ESSENTIAL OIL 463

Dragana Randjelović, V. Savić, V. Topalović, M. Koprivica, J. Nikolić
GROWTH PARAMETERS RESPONSE OF *Ocimum basilicum* 'Genovese' TO PHOSPHATE GLASS AS AN ALTERNATIVE FERTILIZER 471

Milan Grozdanović, M. Mančić, J. Đoković, D. Tanikić, A. Đorđević
INTEGRATED HYBRID SYSTEMS FOR RESIDENTIAL ENERGY AUTONOMY: A LITERATURE REVIEW 478

Milan Nedeljković, S. Mladenović, V. Ćosović, I. Marković, J. Petrović, U. Stamenković
GREEN ENGINEERING APPROACH TO Sn-0.7Cu/xGNS COMPOSITES PRODUCED BY POWDER METALLURGY: MICROSTRUCTURAL AND MECHANICAL PROPERTIES FOR SUSTAINABLE ELECTRONICS 485

Snežana Urošević, M. Vuković
TEXTILE WASTE MANAGEMENT IN THE CONTEXT OF THE CIRCULAR ECONOMY AND ITS SOCIOECONOMIC EFFECTS 490

Danijela Voza, M. Veličković, M. Panić, A. Fedajev, S. Arsić, D. Mladenović
GREEN PURCHASING DETERMINANTS AMONG GENERATION Z: AN EXPLORATORY FACTOR ANALYSIS 497

Marija Ivanović, S. Knežević, Lj. Kljajević, N. Mladenović Nikolić, I. Maksimović, K. Cmiljanović, S. Nenadović
GREEN METAKAOLIN GEOPOLYMERS: SYNTHESIS AND CHARACTERIZATION DURING AGEING 503

Dragi Peltechki
DIAGNOSING CRITICAL RAW MATERIALS SECTOR READINESS IN CANDIDATE COUNTRIES: A PESTLE-BASED ASSESSMENT OF NORTH MACEDONIA 509

Marija Stojanoska, V. Atanasova
SUSTAINABLE TRANSPORT AND FIGHT AGAINST POLLUTION, CASE STUDY 516

Luka Grbović, O. Jakovljević, J. Krizmanić, B. Tubić, M. Kračun Kolarević, S. Anđus, B. Vasiljević
ADDITIONAL RECORDS ON BENTHIC DIATOM *Encyonema Bonapartei* Heudre, C.E. Wetzel & Ector (Cymbellales, Bacillariophyceae) IN WATER BODIES OF THE UVAC SPECIAL NATURE RESERVE (SERBIA) 523

Bojana Tubić, J. Đuknić, N. Marinković, N. Popović, L. Grbović, M. Raković, M. Paunović
AQUATIC MACROINVERTEBRATE FAUNA AT SELECTED SAMPLING SITES IN THE GRADAC RIVER 530

Olga Jakovljević, A. Božić, S. Popović
DIATOM ASSEMBLAGES IN BIOFILMS OF FRUŠKA GORA WATERFALLS (SERBIA) 536

Slađana Popović, Z. Krantić, O. Jakovljević, A. Anđelković, A. Milićević
pH-DEPENDENT GROWTH RESPONSES OF *Chlorella* STRAINS IN BG11 MEDIUM 541

Nataša Kojadinović, S. Đuretanović, M. Radenković, A. Milošković, T. Veličković, M. Jakovljević, V. Simić
ASSESSMENT OF THE LENGTH–WEIGHT RELATIONSHIP AND RELATIVE CONDITION FACTOR OF SCADAR BLEAK IN THREE WESTERN BALKAN LAKES 546

Vesna Obradović, M. Perović, T. Vučković
QUANTIFYING SAMPLING CONTRIBUTION TO MEASUREMENT UNCERTAINTY IN MICROBIOLOGICAL GROUNDWATER ANALYSIS 551

Vesna Obradović, M. Perović, J. Lekić
MEASUREMENT UNCERTAINTY OF WASTEWATER SAMPLING FOR MICROBIOLOGICAL ANALYSIS USING DUPLICATE SAMPLING AND ANOVA APPROACH 556

Maja Nujkić, Ž. Tasić, T. Kalinović, D. Medić, A. Radojević, J. Kalinović, J. Jordanović, S. Đorđievski, N. Apostolov
PREPARATION AND APPLICATION OF MODIFIED ZEOLITE FROM INDUSTRIAL WASTE 561

Vanja Trifunović, S. Milić, Lj. Avramović, S. Vasiljević, D. Medić, V. Nedelkovski, D. Božić
TRANSFORMATION OF WASTE FROM HAZARDOUS TO NON-HAZARDOUS: STABILIZATION OF SOLID RESIDUE OBTAINED AFTER TWO-STEP HYDROMETALLURGICAL TREATMENT OF EAF DUST 568

Isidora Santrač, J. Korać Jačić, M. Milenković, M. Živković
HOW STRUCTURAL MODIFICATIONS INFLUENCE ENVIRONMENTAL RISK: A CASE STUDY OF STEROIDAL DERIVATIVES 576

Jelena Janjić, M. Ćurić
IMPACT OF FOG DISPERSION ON AVIATION AND ENVIRONMENTAL SAFETY 582

Vesna Djikanović, J. Vranković, K. Jovičić
MICRO AND MESOPLASTIC PARTICLES IN WATER AND SEDIMENT IN SPECIAL NATURE RESERVE “OBEDSKA BARA” 590

Marko Pezdevšek, A. Roger, M. Fike, K. Sredenšek
NUMERICAL ASSESSMENT OF THE IMPACT OF FLOATING PHOTOVOLTAIC SYSTEMS ON LAKE THERMAL REGIME 595

Bojana Petrović, M. Jovanović, B. Radović, R. Kovačević, M. Jovašević-Stojanović
SOURCE-ASSOCIATED HEALTH RISKS RELATED TO METALLIC AND CARBONACEOUS PM_{10} FRACTION AT TWO URBAN SITES IN SERBIA 602

Usama Bin Moazzam, H. Nawab, K. Nasir, I. Batool
CLIMATE-INDUCED PROJECT SCOPE CREEP AND COST OVERRUNS IN LONG-HORIZON INFRASTRUCTURE PROJECTS: THE MEDIATING ROLE OF ADAPTIVE RISK RE-ASSESSMENT 610

Student Section – EcoTERS'26

Student: Dragana Kerkez
Mentors: Svetlana Nešović, Kristina Filipović, Jovana Krstić
HEALTH IMPACTS AND PREVENTION STRATEGIES OF URBAN AIR POLLUTION 620

Student: Jelena Zec
Mentors: Milena Rikalović, Dubravka Nikolovski
ASSESSMENT OF THE IMPACT OF FINE SUSPENDED PARTICLES PM_{10} AND LEAD ABSORBED ONTO THEM IN AMBIENT AIR OF PANČEVO ON PUBLIC HEALTH 622

Student: Minja Stojadinović
Mentor: Maja Nujkić
PRESENCE AND INFLUENCE OF PHARMACEUTICAL POLLUTANTS IN THE ENVIRONMENT 624

Student: Nataša Janjić
Mentor: Žaklina Tasić
COPPER CORROSION INHIBITORS IN CHLORIDE ENVIRONMENTS 626

Student: Saška Dumitrašković
Mentors: Milan Gorgievski, Vesna Grekulović
ADSORPTION ISOTHERMS FOR COPPER IONS BIOSORPTION ONTO GRAPE STALKS 628

Student: Veljko Jovanović
Mentor: Maja Nujkić
THE IMPACT OF BIODEGRADABLE PLASTICS ON THE ENVIRONMENT 630

Student: Marina Karabašević
Mentors: Vesna Grekulović, Milan Gorgievski
ELECTROCHEMICAL BEHAVIOR OF COPPER IN PRESENCE OF OAK BARK MACERATE 632

Student: Snežana Nikolić
Mentor: Maja Nujkić
PHOTOCATALYTIC NANOMATERIAL FOR HEAVY METAL REMEDIATION 634

Student: Nataša Apostolov
Mentor: Maja Nujkić
MECHANISMS AND CHALLENGES OF PHOTOCATALYTIC NANOMATERIALS IN HEAVY METAL REMOVAL 636

Students: Nebojša Radović, Aleksa Vizi, Željka Nikolić
Mentors: Ivan Kojić, Ksenija Stojanović
BIODIESEL PRODUCTION FROM SUNFLOWER OIL USING CALCINED CIGARETTE ASH AS A WASTE-DERIVED CATALYST 638

Student: Marija Vesković
Mentor: Antonije Onjia
IDENTIFICATION OF HEAVY METAL SOURCES IN RIVER SEDIMENT IN THE KRUPANJ AREA 640

Student: Aleksandra Jović
Mentor: Maja Nujkić
RECYCLING OF ERDITE AND $KFES_2$ FROM WASTE SLUDGE AS FUNCTIONAL MATERIALS FOR ENVIRONMENTAL PROTECTION 642

Student: Teodora Jogrić
Mentor: Ljubiša Balanović
INFLUENCE OF Ni AND Si ADDITIONS ON THE MICROSTRUCTURE, MECHANICAL PROPERTIES AND CONDUCTIVITY OF CuZn30 ALLOY 644

Student: Jovana Levkić
Mentors: Tanja Kalinović, Jelena Kalinović
ENVIRONMENTAL IMPACT AND EMISSION CONTROL IN PYROMETALLURGICAL COPPER PRODUCTION 646

Student: Mladen Radić
Mentors: Jelena Kalinović, Ana Radojević
IMPACT OF ARTIFICIAL INTELLIGENCE USE ON AIR POLLUTION 648

Student: Nataša Đorđević
Mentors: Jelena Kalinović, Tanja Kalinović
PLANTS AS BIOINDICATORS OF AIR POLLUTION 650

Author index 652

Original Research

CHARACTERIZATION OF THE Sn78Bi22 ALLOY AS AN ENVIRONMENTALLY FRIENDLY LEAD-FREE SOLDER

DOI: 10.5937/EcoTER26410S

Uroš Stamenković[1,a*], Ivana Marković[1,b], Dragan Manasijević[1,c], Kristina Božinović[1,d], Milan Nedeljković[1,e], Avram Kovačević[1,f]

University of Belgrade, Technical Faculty in Bor, Vojske Jugoslavije 12, 19210 Bor, SERBIA

[a] https://orcid.org/0000-0002-7579-2159 [b] https://orcid.org/0000-0003-4431-9921

[c] https://orcid.org/0000-0002-7828-8994 [d] https://orcid.org/0000-0002-9834-448X

[e] https://orcid.org/0000-0002-7927-1334 [f] https://orcid.org/0000-0003-4009-4876

Abstract

The development of reliable lead-free solder alloys remains essential for applications in the electronics industry. This paper investigates the mechanical, electrical, and microstructural properties of a Sn78Bi22 solder alloy. The alloy was prepared by melting and casting, followed by a homogenization heat treatment. Tensile testing, Vickers microhardness measurements, electrical conductivity testing, and SEM/EDS microstructural analysis were performed at room temperature. The investigated alloy exhibited enhanced ultimate tensile strength (~93 MPa) and microhardness (45.5 HV0.05) compared with pure Sn, while electrical conductivity decreased to 5.4 MS/m. These changes were attributed to solid-solution strengthening, grain refinement, and the formation of a Bi-rich secondary phase, which also promoted brittle fracture during tensile testing. Microstructural observations revealed a Sn matrix with finely distributed Bi-rich phases, particularly along grain boundaries. The results contribute additional experimental data on the mechanical, electrical, and microstructural characteristics of non-eutectic Sn–Bi solder alloys.

Keywords: Sn78Bi22 alloy, mechanical properties, electrical conductivity, microstructure.

INTRODUCTION

Sn–Pb solders have been extensively used in the electronics industry for decades due to their excellent solderability, low melting temperature, low cost, and favourable mechanical properties. However, lead is unequivocally harmful to human health and the environment, necessitating the gradual elimination of lead-containing materials from electronic products. With the implementation of the Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS) directives, the European Union mandated the use of lead-free solder alloys in electronic assemblies [1,2].

In response to these regulations, numerous lead-free solder systems have been investigated over the past two decades, including Sn–Cu, Sn–In, Sn–Zn, Sn–Ag–Cu, and Sn–Bi alloys [2]. Among these candidates, the Sn–Bi system has attracted considerable attention due to its relatively low melting temperature and good wettability. In particular, the eutectic Sn58Bi

* *ustamenkovic@tfbor.bg.ac.rs*

alloy has been extensively studied and reported in the literature, as summarized by Kamaruzzaman *et al*. [3]. Despite its industrial applicability, the high bismuth content in eutectic Sn–Bi alloys leads to pronounced brittleness, which represents a significant drawback in terms of mechanical reliability and susceptibility to brittle fracture in solder joints.

To address these limitations, recent research efforts have increasingly focused on non-eutectic Sn–Bi alloys with lower bismuth contents (typically up to ~20 wt.% Bi), aiming to achieve a balance between mechanical strength, ductility, and functional properties. Shen investigated the mechanical strength and thermal behaviour of Sn–2.5Bi and Sn–5Bi alloys [4]. Yang *et al*. examined the effects of graphene nanosheets (GNS) on the microstructure and properties of Sn–20Bi solder alloys [2]. Lai *et al*. focused on non-eutectic Sn–Bi alloys, with particular emphasis on microstructural evolution and fracture behaviour [5].

Furthermore, Wang *et al*. reviewed recent progress in the development of low-temperature Sn–Bi solders and concluded that the intrinsic brittleness of bismuth remains a critical challenge, especially under mechanical shock loading in electronic devices. In addition, segregation of Bi-rich phases and excessive growth of the intermetallic compound (IMC) layer were identified as major reliability concerns that can compromise the long-term performance of solder joints [6].

Although substantial research has been devoted to the mechanical, microstructural, and physical properties of non-eutectic Sn–Bi solder alloys, further systematic investigations are still required to fully understand the structure–property relationships in this alloy system. In this context, the present study contributes additional experimental data and analysis to the existing body of knowledge on non-eutectic Sn–Bi solder alloys.

MATERIALS AND METHODS

Alloy preparation

Commercially pure tin (99.9 wt.%) and bismuth (99.9 wt.%) were used to prepare the Sn78Bi22 alloy. The metallic granules were placed in a graphite crucible and melted in a muffle furnace at 350 °C. During melting, the crucible was covered with a carbon piece to minimize oxidation. After complete melting, the alloy was mechanically stirred using a pure graphite stirrer to ensure chemical homogeneity.

The molten alloy was subsequently cast into a steel mold with a diameter of 13 mm. The as-cast samples were then homogenized in an electric furnace at 150 °C for 20 h to promote a more uniform distribution of Bi within the Sn matrix, followed by air cooling to room temperature.

After homogenization, the samples were sectioned for further characterization using a Struers Mesotom metallographic cutting machine.

Tensile strength measurements

To determine the tensile strength, a 5 mm diameter wire of the Sn78Bi22 alloy was prepared. The homogenized cast rod (initial diameter 13 mm) was gradually reduced to 5 mm using a calibrated Joliot rolling mill. The reduction process involved cold rolling with intermediate annealing steps to prevent excessive strain accumulation and cracking.

After reaching the final diameter, the wire was subjected to a final annealing treatment to eliminate residual deformation and ensure that the mechanical properties were representative of the homogenized state. Tensile testing was performed using a Mohr–Federhaff–Losenhausen universal testing machine.

Microhardness measurements

Microhardness measurements were carried out using a PMT-3 microhardness tester employing the Vickers method, in accordance with ASTM E384 [7]. A load of 0.5 N and a dwell time of 15 s were applied. Prior to testing, the sample surface was polished to a mirror finish. Five indentations were made at different locations on the sample surface, and the reported microhardness value represents the average of these measurements.

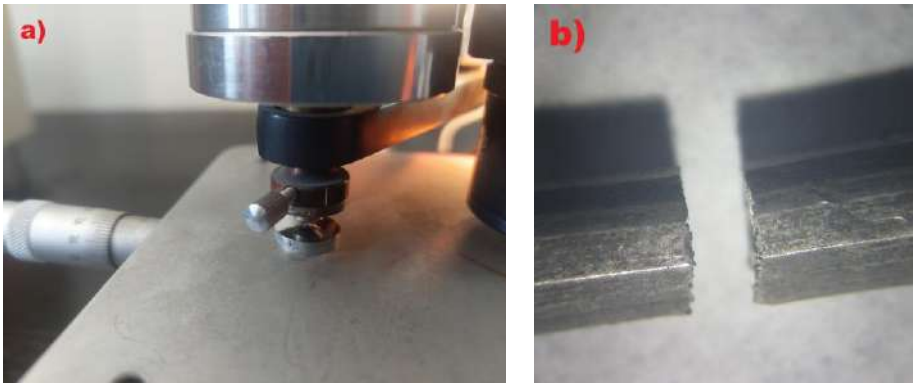


Figure 1 *Different measurements performed on the Sn78Bi22 alloy: (a) Vickers microhardness indentation on a polished surface; (b) fractured wire specimen after tensile testing, indicating brittle fracture behaviour*

Electrical conductivity measurements

Electrical conductivity was measured using a Foerster Sigmatest 2.063 conductivity tester. Three measurements were performed on each sample, and the average value was reported.

Microstructural characterization

Samples for microstructural analysis were prepared using standard metallographic procedures. Wet grinding was performed using SiC papers with grit sizes of #400, #600, #800, #1000, #2000, and #3000, followed by polishing with Al_2O_3 suspensions of 0.3 µm and 0.05 µm particle size.

The microstructure was revealed by chemical etching for 15 s using a solution composed of 2 ml HCl, 2 ml HNO_3, and 96 ml C_2H_5OH. Scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS) analyses were conducted using a Tescan Vega 3 LMU scanning electron microscope equipped with an Oxford Instruments X-act EDS detector.

RESULTS AND DISCUSSION

Tensile strength is one of the most critical mechanical properties in solder materials, as it directly determines the ability of solder joints to withstand deformation and various types of mechanical loading during service. Figure 2 presents the engineering stress–strain curve of

the investigated Sn78Bi22 alloy. Pure β-tin is known to exhibit very low tensile strength at ambient conditions; reported ultimate tensile strength (UTS) values of approximately 16 MPa have been obtained from quasi-static tensile testing of bulk polycrystalline Sn, as reported by Zhou *et al*. [8].

The addition of bismuth leads to a pronounced improvement in tensile strength, as clearly evidenced in Figure 2. In the present study, the Sn78Bi22 alloy exhibited an ultimate tensile strength of approximately 93 MPa. This substantial increase in UTS is primarily attributed to the incorporation of 22 wt.% Bi, which promotes grain refinement of the Sn-rich matrix, solid-solution strengthening due to partial Bi solubility in Sn, and dispersion strengthening associated with the formation of finely distributed Bi-rich phases. These Bi-induced microstructural and compositional features act as effective obstacles to dislocation motion, thereby significantly enhancing the tensile strength of the alloy [5]. Similar trends have been reported in the literature: Yang *et al.* [2] observed slightly lower UTS values for Sn80Bi20 solder alloys, whereas Lai *et al.* [5] reported UTS values close to 95 MPa, which is in good agreement with the results obtained in the present work.

However, the supersaturation of the Sn matrix with the brittle Bi phase, while beneficial for strength enhancement, also promotes brittle fracture behaviour, as reported by Zhou *et al.* [9] and as observed on the fractured tensile specimen shown in Figure 1b.

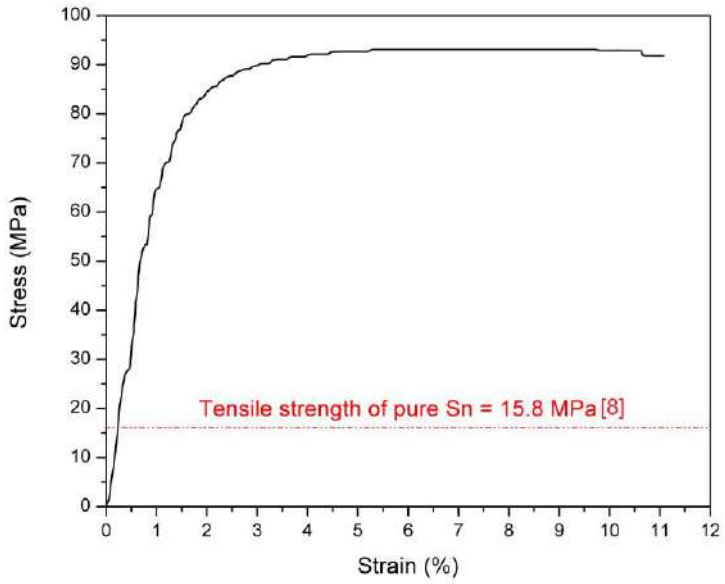


Figure 2 *Stress-strain curve of the investigated Sn78Bi22 alloy*

The microhardness results are consistent with the tensile strength measurements. Pure β-Sn exhibits very low hardness, with reported values in the range of 8–10 HV, as documented in the literature [4,10]. In the present study, the Sn78Bi22 alloy exhibited a significantly higher microhardness of 45.5 $HV_{0.05}$.

This pronounced increase in hardness is attributed to the same strengthening mechanisms identified in the tensile investigation, namely grain refinement, solid-solution strengthening, and dispersion strengthening induced by Bi addition. For comparison, Shen *et al.* [4] reported

a hardness of approximately 20 HV for Sn95Bi5, while Thongchai *et al*. [10] reported values of around 17 HV for Sn96Bi4 alloys. Considering both the literature data and the approximately sixfold increase in ultimate tensile strength relative to pure Sn (Figure 2), the observed rise in microhardness is in good agreement with the enhanced mechanical performance of the Sn78Bi22 alloy.

Electrical conductivity is a critical property in solder technology, as solder joints are required to efficiently transmit electrical power and signals between electronic components. Pure tin exhibits relatively low electrical conductivity compared to copper, with reported values of approximately 15–16% IACS, corresponding to ~8–9 MS/m at room temperature, depending on purity and microstructural condition. In contrast, bismuth possesses a significantly lower electrical conductivity, reported to be approximately 0.77 MS/m [11].

In the present study, the Sn78Bi22 alloy exhibited an electrical conductivity of 5.4 MS/m, which lies between the conductivity values of pure Sn and pure Bi. The observed reduction in electrical conductivity relative to pure Sn is expected and can be attributed to several alloying- and microstructure-related factors. First, the substantial atomic size mismatch between Sn and Bi introduces lattice distortion, which enhances electron scattering. Second, the addition of Bi leads to the formation of a supersaturated solid solution of Bi in the Sn matrix, further increasing scattering of conduction electrons. Third, the presence of Bi-rich phases within the microstructure introduces additional phase boundaries that act as electron scattering centres. Finally, Bi-induced grain refinement increases the total grain boundary area, which also contributes to increased resistivity.

Collectively, these effects result in an increase in electrical resistivity in accordance with Matthiessen's rule, whereby different scattering mechanisms contribute additively to the total resistivity of the alloy [12]. Similar reductions in electrical conductivity with increasing Bi content in Sn–Bi solder alloys have also been reported by other authors, confirming the trends observed in the present work [13,14].

Microstructural analysis further supports the previously discussed mechanical and electrical property trends. Figure 3 presents the SEM–EDS characterization of the Sn78Bi22 alloy. The microstructure consists of a supersaturated Sn–rich matrix with relatively fine grains, within which a Bi-rich phase is distributed throughout the structure, preferentially along grain boundaries. In backscattered electron (BSE) images, the Bi-rich phase appears brighter due to its higher atomic number and is identified by EDS spectra 1 and 3, whereas the β-Sn matrix corresponds to spectrum 2, as confirmed by the EDS analysis summarized in Table 1.

Such a microstructural configuration, characterized by a Sn-rich matrix reinforced by Bi-rich regions at grain boundaries and within the matrix, is consistent with observations reported in the literature for hypoeutectic Sn–Bi solder alloys [2,4,5,9,10].

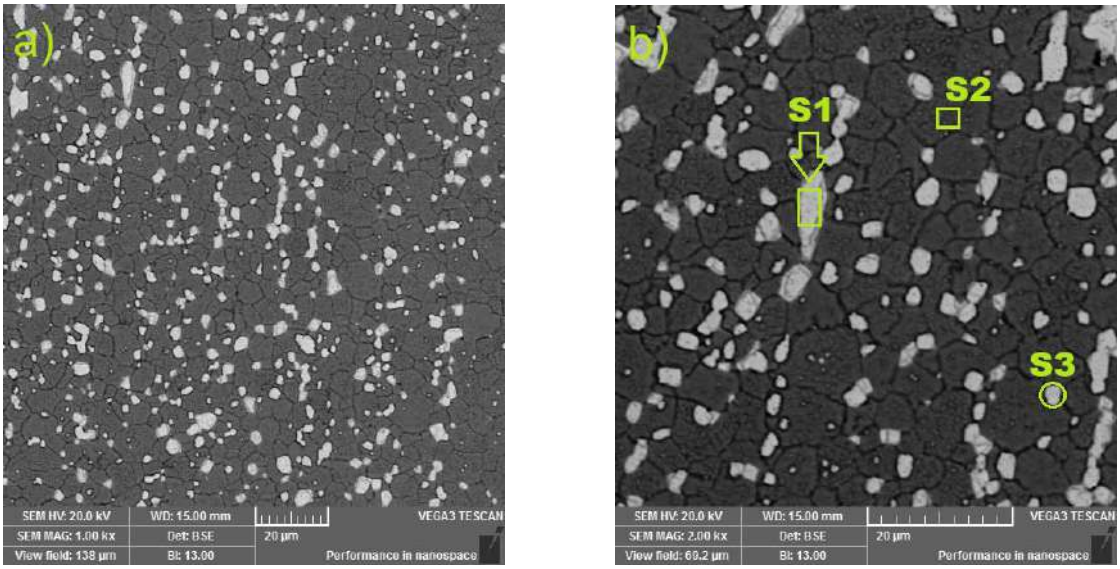


Figure 3 *SEM–EDS analysis of Sn78Bi22 alloy: a) x1000 magnification; b) x2000 magnification*

Table 1 *EDS analysis of the Sn78Bi22 sample*

Spectrum	*Bi*	*Sn*
Spectrum 1	95.31	4.69
Spectrum 2	2.95	97.05
Spectrum 3	84.6	15.4

CONCLUSIONS

In this study, the Sn78Bi22 solder alloy was systematically investigated with respect to its mechanical, electrical, and microstructural properties. The addition of bismuth resulted in a pronounced increase in ultimate tensile strength and microhardness, accompanied by a reduction in electrical conductivity when compared to pure tin. These changes in properties are attributed to several Bi-induced strengthening mechanisms, including solid-solution strengthening of the Sn-rich matrix, the formation of a Bi-rich secondary phase, and grain refinement effects.

Microstructural analysis confirmed the presence of a supersaturated Sn-rich matrix with Bi-rich phases distributed throughout the microstructure, particularly along grain boundaries, providing microstructural evidence that supports the observed mechanical strengthening and electrical conductivity trends.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for financial support according to the contract with registration No. 451-03-34/2026-03/ 200131.

REFERENCES

[1] Zhang, L., Tu, K.N. Mater. Sci. Eng. R Rep. 2014, 82, 1–32.

[2] Yang, W., Qin, W., Wu, J., *et al*. Materials. 2023, 16, 1550.

[3] Kamaruzzaman, L.S., Goh, Y. Solder. Surf. Mt. Technol. 2022, 34 (5), 300–318.

[4] Shen, Y.-A. JOM. 2023, 75 (11), 4922–4930.

[5] Lai, Z., Ye, D. J. Mater. Sci.: Mater. Electron. 2016, 27, 3182–3192.

[6] Wang, F., Chen, H., Huang, Y. *et al*. J. Mater. Sci.: Mater. Electron. 2019, 30, 3222–3243.

[7] ASTM E384–22. Standard Test Method for Microindentation Hardness of Materials. ASTM International, 2022. Accessed 23 January 2026. Available from: https://store.astm.org/e0384-22.html

[8] Zhou, J., Tan, X.F., McDonald, S.D. *et. al.* Materials. 2022, 15 (23), 8321.

[9] Zhou, S., Zhang, Y., Duan, J. *et al*. RSC Adv. 2023, 13, 35161–35171.

[10] Thongchai, C., Lohwongwatana, B., Puncreobutr, C. *et. al*. Eng. J. 2018, 22 (5), 171–183.

[11] Electrical Conductivity of the elements. Accessed 23 January 2026. Available from: https://periodictable.com/Properties/A/ElectricalConductivity.an.html

[12] Callister, Jr. W.D., Materials Science and Engineering: An Introduction, 3rd edn. New York: John Wiley & Sons, 1994.

[13] Lv, X., Pan, Z., Liu, Y. *et al*. Metals. 2025, 15, 157.

[14] Tan, X. F., Hao, Q., Zhou, J. *et al*. J. Electron. Mater. 2024, 53, 1183–1191.

ISBN 978-86-6305-171-3

eco.tfbor.bg.ac.rs

