



University of Belgrade, Technical Faculty in Bor



# ECOENTER

**30<sup>th</sup> International Conference Ecological Truth  
& Environmental Research  
2023**

# Proceedings

**Editor  
Prof. Dr Snežana Šerbula**





University of Belgrade, Technical Faculty in Bor



# ECOE 2023

30<sup>th</sup> International Conference Ecological Truth  
& Environmental Research  
2023

# Proceedings

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Prof. Dr Snežana Šerbula



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## **PREFACE**

*The 30<sup>th</sup> international conference Ecological Truth & Environmental Research – EcoTER'23 kept three areas in focus: ecology, environmental protection and sustainable development. The conference will be held on Mt Stara Planina in hotel Stara Planina, Serbia, 20–23 June 2023. The monograph is published on the occasion of the 30th anniversary of the conference. On behalf of the scientific and organizing committee, it is a great honor and pleasure to wish all the participants a warm welcome to the conference.*

*The monograph is published on the occasion of the 30<sup>th</sup> anniversary of the conference.*

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

*The 30<sup>th</sup> international conference Ecological Truth & Environmental Research – EcoTER'23 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology, the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica, the University of Zagreb, Faculty of Metallurgy – Sisak, the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Association of Young Researchers, Bor.*

*These Proceedings 103 papers from the authors coming from the universities, research institutes and industries in 11 countries: Australia, USA, Brazil, Spain, Portugal, Libya, Italy, Bulgaria, Bosnia and Herzegovina, North Macedonia, and Serbia.*

*As a part of this year's conference, the 5<sup>th</sup> Student Session – EcoTERS'23 is being held. We appreciate the contribution of the students and their mentors who have also participated in the conference.*

*The support of the Gold donor and their willingness and ability to cooperate has been of great importance for the success of the EcoTER'23. The organizing committee would like to extend their appreciation and gratitude to the Gold donor of the conference for their donation and support.*

*We appreciate the effort of all the authors who have contributed to these Proceedings. We would also like to express our gratitude to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the conference participants for their support to the EcoTER'23. Sincere thanks go to all the people who have contributed to the successful organization of the EcoTER'23.*

*Prof. Snežana Šerbula,*

*President of the scientific and organizing committee*



## TABLE OF CONTENTS

### Plenary Lecture

- Lidija Mančić, M. E. Rabanal, B. Marinković*  
OPTICALLY ACTIVE NANOMATERIALS FOR ENVIRONMENTAL  
REMEDICATION 2

### Invited Lectures

- Aleksandra A. Jovanović*  
THE EXTRACTION OF ACTIVE COMPOUNDS FROM PLANT WASTE:  
THE POTENTIAL IN HUMAN AND INDUSTRIAL APPLICATIONS AS  
THE CONCEPT OF ZERO WASTE IN THE CIRCULAR ECONOMY 7
- Tanja Brdarić*  
ELECTROCHEMICAL ADVANCED OXIDATION PROCESSES FOR  
WASTEWATER TREATMENT: RECENT ADVANCES AND  
PERSPECTIVES 18
- Mirjana Marković, S. Radmanović, Đ. Čokeša, N. Potkonjak*  
HUMIC ACIDS IN THE ENVIRONMENT 30
- Mira Stanković, M. Prokopijević, D. Bartolić, J. Stevanović, F. Andrić, K. Radotić*  
ADVANCED OPTICAL TOOLS APPLIED ON HONEY SAMPLES FOR  
BEE HEALTH STATUS MONITORING 40
- Dragana Bartolić, M. Nikolić, M. Stanković, M. Prokopijević, M. Algara,  
S. Stanković, K. Radotić*  
ESTIMATION OF THE ANTIFUNGAL ACTIVITY OF THE TWO  
DIFFERENT CARBON DOTS AGAINST *Aspergillus flavus* 47

### Conference Papers

#### Environmental monitoring and impact assessment

- Ana Čučulović, J. Stanojković, R. Čučulović, M. Stanković*  
RADIOACTIVITY IN SOIL AND MOSSES FROM THE SPECIAL  
NATURE RESERVE OF ZASAVICA IN 2021 56
- Djurdja Petrov, M. Ocokoljić, N. Galečić, D. Skočajić, I. Simović*  
*Chaenomeles* × *superba* 'PINK LADY' IN DESIGNING PRIVATE  
GARDENS IN CONDITIONS OF CLIMATE CHANGE 62

<b>Mirjana Đurašević, I. Čeliković, I. Kandić, T. Milanović, A. Samolov, N. Mladenović Nikolić, A. Kandić</b>	
ACTIVITY CONCENTRATIONS OF $^{210}\text{Pb}$ , $^{137}\text{Cs}$ , AND $^{40}\text{K}$ IN WILD MUSHROOMS FROM SERBIA AND THEIR EFFECTIVE DOSE TO INGESTION	69
<b>Jelena Čović, M. Z. Momčilović, M. Randelović</b>	
LANTHANUM IMMOBILIZED ONTO GRAPHENE AS A CATALYST DESIGNED FOR ELECTROCHEMICAL APPLICATIONS	75
<b>Jelena Čović, M. Z. Momčilović, M. Randelović</b>	
NITROGEN DOPED CARBON MICROSPHERES SUPPORTED ONTO MWCNT AS NOVEL ELECTRODE MATERIAL	82
<b>Aleksandra Nesic, S. Meseldzija, M. Momcilovic</b>	
SUSTAINABLE PECTIN MONOLITH CRYOGELS	88
<b>Daniela Djikanović, O. Prodanović, J. Dragišić Maksimović, J. Jovanović, A. Kalauzi, D. Spasojević, K. Radotić</b>	
INVESTIGATION OF SILICA-LIGNIN INTERACTION. APPLICATION OF AFM AND FLUORESCENCE TECHNIQUES	94
<b>Vesna Djikanović, J. Čanak Atlagić, K. Zorić, S. Andjus, M. Ilić, V. Nikolić, K. Jovičić</b>	
COMPOSITION OF THE FISH COMMUNITY OF THE RIBNICA RIVER WITH RESPECT TO THE CONSERVATION STATUS	99
<b>Nikola Marinković, B. Tubić, A. Atanacković, N. Popović, J. Tomović, M. Raković, M. Paunović</b>	
INDICATIVE ECOLOGICAL STATUS ASSESSMENT OF RIBNICA RIVER (KOLUBARA BASIN) BASED ON AQUATIC MACROINVERTEBRATES	104
<b>Tamara Petronijević, I. Kostić Kokić, T. Anđelković, B. Zlatković, K. Kitanović, D. Bogdanović, N. Stanković</b>	
INFLUENCE OF FREEZING ON NITRATE AND NITRITE CONTENT IN RADISH, PARSLEY LEAF AND CELERY ROOT	109
<b>Marija Matić, D. Pavlović, V. Perović, D. Sekulić, N. Radulović, M. Mitrović, P. Pavlović</b>	
DETERMINATION OF PTEs CONTENT IN LIVESTOCK FODDER AND SOIL IN THE VICINITY OF THERMAL POWER PLANTS AND ASH DISPOSAL SITES	115
<b>Sonja Veljović Jovanović, S. Milić Komić, B. Živanović, A. Sedlarević Zorić, N. Šušić</b>	
LEAF NITROGEN BALANCE INDEX USED TO MONITOR STRESS RESPONSE TO AIR POLLUTION OF DECIDUOUS TREE SPECIES GROWN IN URBAN ZONE OF BELGRADE	122

<b>Bojana Živanović, S. Milić Komić, A. Sedlarević Zorić, A. Jelušić, N. Šušić, S. Marković, S. Veljović Jovanović</b>	
USE OF BIOCHEMICAL METHODS FOR ASSESING OXIDATIVE STRESS IN TREES IN URBAN AREA DURING GROWING SEASON	129
<b>Nikola Šušić, S. Milić Komić, B. Živanović, A. Jelušić, S. Marković, A. Sedlarević Zorić, S. Veljović Jovanović</b>	
ACCLIMATION OF PEDUNCULATE OAK SEEDLINGS TO DIFFERENT LIGHT CONDITIONS IN THE FIRST MONTHS AFTER GERMINATION	135
<b>Božica Vasiljević, J. Đuknić, N. Marinković</b>	
BENTHIC DIATOMS AS PROXY FOR THE ECOLOGICAL CONDITIONS OF THE RIBNICA RIVER, SERBIA	141
<b>Milanka Negovanović, L. Kričak, S. Milanović, J. Marković, N. Simić, S. Ignjatović</b>	
BLASTING MATS FOR THE PROTECTION OF PEOPLE, STRUCTURES AND THE ENVIRONMENT IN PROXIMITY TO THE BLAST SITE	147
<b>Aleksandra Kolarski, V. Srečković, Z. Mijić</b>	
INFLUENCES OF EXTREME SOLAR ACTIVITY ON EARTH ENVIRONMENT – CASE STUDY	154
<b>Maja Poznanović Spahić, A. Gulan, D. Spahić, P. Tančić, S. Sakan, S. Petrović</b>	
AVAILABILITY OF TOXIC ELEMENTS IN ROADSIDE SOILS (HIGHWAY 75, VOJVODINA, SERBIA): IS THERE ANY SIGNIFICANT CONTAMINATION RISK?	160
<b>Tanja Kalinović, A. Radojević, J. Kalinović, J. Milosavljević, S. Šerbula</b>	
MULTICRITERIA EFFICIENCY ASSESSMENT OF THE PINE TREE POTENTIAL FOR THE PHYTOREMEDIATION OF COPPER	167
<b>Žaklina Tasić, M. Petrović Mihajlović, A. Simonović, M. Radovanović, M. Antonijević</b>	
ELECTROCHEMICAL SENSING OF FOLIC ACID	173
<b>Vanja Trifunović, S. Milić, Lj. Avramović, M. Antonijević, M. Radovanović</b>	
POTENTIAL ENVIRONMENT POLLUTANT – INTERMEDIATE PRODUCT OF THE STEEL PRODUCTION PROCESS	179
<b>Natalija Ognjanović, V. Nedelkovski, S. Stanković, S. Milić</b>	
BIOPESTICIDES IN THE ENVIRONMENT	185
<b>Urban and industrial ecology</b>	
<b>Goran Milentijević, M. Agatonović, M. Rančić, M. Milosavljević</b>	
ENVIRONMENTALLY ACCEPTABLE PROCEDURE FOR THE SYNTHESIS OF TETRAETHYLTHIURAMMONOSULFIDE TETS	191

<b><i>Andela Stojić, D. Tanikić, E. Požega</i></b>		
TECHNOLOGICAL PROCESSES AS SOURCES OF POLLUTION IN THE ENVIRONMENT		198
<b><i>Aleksandar Lisica, N. Stojanović, M. Veselinović, J. Petrović, N. Stavretović, M. Tešić</i></b>		
LONDON PLANE ( <i>Platanus × acerifolia</i> (Aiton) Willd.) IN THE STREET TREE LINES OF THE OLD TOWN IN BELGRADE		203
<b><i>Djordja Petrov, M. Ocokoljić, N. Galečić, D. Skočajić</i></b>		
APPLICATION OF SPECIES OF THE GENUS <i>Parthenocissus</i> L. IN URBAN GREEN INFRASTRUCTURE – STATE AND PERSPECTIVES		210
<b><i>Djordja Petrov, M. Ocokoljić, N. Galečić, D. Skočajić, I. Simović</i></b>		
SECOND FLOWERING OF <i>Philadelphus coronarius</i> L. IN GREEN-BLUE INFRASTRUCTURE OF BELGRADE		216
<b><i>Dragana Pavlović, M. Matić, V. Perović, O. Kostić, D. Sekulić, M. Mitrović, P. Pavlović</i></b>		
EFFECTS OF SO <sub>2</sub> AND NO <sub>2</sub> ON THE PHOTOSYNTHETIC EFFICIENCY AND CATALASE ANTIOXIDATIVE ENZYME ACTIVITY IN <i>Betula pendula</i> Roth		222
<b><i>Ermenegilda Vitale, P. Napoletano, C. Arena, A. De Marco</i></b>		
PLANT-SOIL RELATIONSHIPS IN MEDITERRANEAN SPECIES GROWN ON TECHNOSOLS ENRICHED WITH COMPOST		228
<b>Air, water and soil pollution, prevention and control</b>		
<b><i>Milica Blažić, M. Milovanović, T. Sekulić, V. Stupar, Z. Živković</i></b>		
IMPACTS OF PESTICIDE APPLICATION ON THE ENVIRONMENT		235
<b><i>George Vuković, D. Kovačević, N. Đorđević, M. Perić, S. Knežević, M. Nikolić, B. Vlahović, V. P. Pavlović, G. Rašić, S. Nenadović, M. Ivanović, M. Mirković, V. B. Pavlović</i></b>		
GREEN SYNTHESIS OF GEOPOLYMER-POLYURETHANE COMPOSITES FOR EM SHIELDING		241
<b><i>Ana Vukmirović, B. Obrovski, S. Vukmirović, I. Mihajlović</i></b>		
APPLICATION OF STATISTICAL METHODS FOR THE ANALYSIS OF WASTEWATER TREATMENT PLANT EFFICIENCY		247
<b><i>Ivana Mihajlović, A. Hgeig, N. Živančev, M. Petrović, M. Novaković</i></b>		
COMPARISON OF DIFFERENT SORBENTS IN THE HERBICIDE REMOVAL FROM WATER		251
<b><i>Aleksandar Krstić, I. Bracanović, D. Vasić Anićijević, A. Kalijadis</i></b>		
VALLME PREPARATION METHOD FOR THE DETERMINATION PHARMACEUTICALS IN WATER		256

<b>Marija Koprivica, J. Petrović, J. Dimitrijević, M. Ercegović, M. Simić, M. Grubišić</b> REMOVAL EFFICIENCY OF HEAVY METAL IONS FROM AQUEOUS SOLUTION WITH WASTE TREE BIOMASS HYDROCHARS	261
<b>Nevena Surudžić, D. Spasojević, M. Stanković, M. Spasojević, R. G. A. Elgahwash, R. Prodanović, O. Prodanović</b> HORSE RADISH PEROXIDASE IMMOBILIZATION WITHIN MICRO-BEADS OF OXIDIZED TYRAMINE-ALGINATE FOR PHENOL REMOVAL FROM WASTEWATER	267
<b>Dragica Spasojević, O. Prodanović, N. Surudžić, D. Djikanović, J. Simonović Radosavljević, K. Radotić, R. Prodanović</b> WASTEWATER TREATMENT BY AMINATED PEROXIDASE IN ALGINATE HYDROGEL	272
<b>Branislava Matić, M. Milić</b> CONTRIBUTION OF INSTITUTE OF PUBLIC HEALTH OF SERBIA IN MONITORING TRAFFIC-INDUCED AIR POLLUTION IN BELGRADE	276
<b>Nenad Malić, U. Matko, M. Trbić, R. Pijunović, M. Marković</b> ALTERNATIVE METHODS OF REHABILITATION (SOIL RECOVERY), RECLAMATION AND REMEDIATION OF MINE TECHNOSOLS	283
<b>Snežana B. Simić, K. A. Markeljić</b> PRELIMINARY ECOLOGICAL STATUS ASSESSMENT OF THE GROŠNICA RIVER BASED ON PHYTOBENTHOS	289
<b>Snežana B. Simić, N. B. Đorđević</b> AN ASSESSMENT OF THE ECOLOGICAL POTENTIAL OF ŠUMARICE RESERVOIRS (CENTRAL SERBIA) BASED ON PHYTOPLANKTON	295
<b>Miloš Prokopijević, M. Stanković, D. Bartolić, A. Lj. Mitrović, K. Radotić</b> FLUORESCENCE CHARACTERISATION OF BISPENOL A IN VARIOUS SOLVENTS AND DRINKING WATER	302
<b>Slobodan Ničković, L. Ilić, S. Petković, G. Pejanović, A. Huete, Z. Mijić</b> NOVEL APPROACH IN AIRBORNE POLLEN DISPERSION MODELLING	306
<b>Nena Velinov, S. Najdanović, M. Petrović, M. Radović Vučić, M. Kostić, J. Mitrović, A. Bojić</b> THE APPLICATION OF SORBENT SYNTHESIZED USING ULTRASOUND FOR REMOVAL OF TEXTILE DYE	312
<b>Milica Petrović, S. Najdanović, N. Velinov, S. Rančev, D. Radivojević, M. Radović Vučić, A. Bojić</b> ATMOSPHERIC PRESSURE CORONA PLASMA DEGRADATION OF REACTIVE ORANGE 4 IN DEIONIZED AND RIVER WATER	318

<b>Slobodan Najdanović, M. Petrović, N. Velinov, M. Kostić, J. Mitrović, D. Bojić, A. Bojić</b>	
THE INFLUENCE OF TYPE OF SOLVENT ON THE ELECTROCHEMICALLY SYNTHESIZED SORBENTS BASED ON BASIC BISMUTH NITRATES	324
<b>Milena Dimitrijević, S. Kovačević, U. Jovanović, M. Stanić, M. Opačić, I. Santrač, M. Tanović, V. Čurić, I. Spasojević</b>	
APPLICATION OF MICROALGA <i>Chlorella sorokiniana</i> IN WASTEWATER BIOREMEDIATION – CASE OF LAKE ROBULE	330
<b>Milan Gorgievski, M. Marković, N. Štrbac, V. Grekulović, M. Zdravković</b>	
ADSORPTION ISOTHERMS FOR COPPER IONS BIOSORPTION ONTO ONION PEELS	335
<b>Sonja Stanković, V. Nedelkovski, M. Radovanović, S. Milić</b>	
MECHANISM AND KINETICS OF ELECTROCATALYTIC OXIDATION OF PHENOL	341
<b>Jelena Milosavljević, S. Šerbula, A. Radojević, T. Kalinović, J. Kalinović</b>	
ECOENZYMATIC STOICHIOMETRY AS AN EMERGING METHOD IN THE ASSESSMENT OF SOIL HEAVY METAL POLLUTION	348
<b>Protection and preservation of natural resources</b>	
<b>Mihajlo Stanković</b>	
ORCHIDS OF THE ZASAVICA SPECIAL NATURE RESERVE	354
<b>Gordana Šekularac, M. Aksić, T. Dimitrijević (ex. Ratknić), M. Vranešević, N. Gudžić, M. Ratknić</b>	
CLIMATIC BALANCE OF THE WATER FOR THE SOIL OF THE KRUŠEVAC REGION IN CENTRAL SERBIA	361
<b>Gordana Šekularac, M. Aksić, T. Dimitrijević (ex. Ratknić), M. Vranešević, S. Gudžić, N. Gudžić, M. Ratknić</b>	
INFLUENCE OF IRRIGATION METHOD ON THE OCCURRENCE AND INTENSITY OF THE GRAY MOLD OF LETTUCE	367
<b>Aleksandar Stevanović, T. Sekulić, M. Blažić, N. Radić, A. Popović, V. Stupar</b>	
THE IMPACT OF IRRIGATION ON THE QUALITY OF THE ENVIRONMENT AND WATER RESOURCES	373
<b>Aleksandar Stevanović, M. Saulić, M. Blažić, V. Stupar, D. Stojićević, Z. Živković</b>	
BIOPREPARATIONS IN THE FUNCTION OF ORGANIC AGRICULTURE IN FRUIT GROWING AND VITICULTURE	379
<b>Vladanka Stupar, T. Sekulić, M. Blažić, N. Radić, A. Popović, A. Stevanović</b>	
IRRIGATION – IMPACT ON SOIL AS AN ENVIRONMENTAL FACTOR	385

<b>Milan Nedeljković, S. Mladenović, J. Petrović</b>	
A RENEWABLE ENERGY SOURCES AND SUSTAINABLE DEVELOPMENT EQUATION	391
<b>Ecological ethics and environmental education</b>	
<b>Tatjana Miljojčić</b>	
FORGING A SUSTAINABLE FUTURE: THE CIRCULAR ECONOMY IN THE FASHION INDUSTRY	396
<b>Ecotoxicology and environmental safety</b>	
<b>Darko Anđelković, M. Branković</b>	
CITRATE BUFFERED QuEChERS vs SIMPLIFIED SAMPLE PREPARATION METHOD: COMPARATIVE LC/MS ANALYSIS OF PESTICIDES IN APPLES	402
<b>Darko Anđelković, M. Branković</b>	
APPLICABILITY OF THE QuEChERS IN NON-CHROMATOGRAPHY-BASED PESTICIDE ANALYSIS IN APPLES	407
<b>Darko Anđelković, M. Branković</b>	
ESI vs APCI IN SELECTED PESTICIDES MS DETECTION IN APPLES	413
<b>Tamara Petronijević, I. Kostić Kokić, Dj. Milošević, M. Stojković Piperac, N. Stanković, T. Anđelković</b>	
DIFFERENT GROWTH RESPONSES OF SELECTED REPRESENTATIVES OF PHYTOPLANKTON TO THE PRESENCE OF THE ANTIBIOTIC VANCOMYCIN	420
<b>Tamara Petronijević, I. Kostić Kokić, T. Anđelković, B. Zlatković, D. Stajić, D. Bogdanović, N. Stanković</b>	
DETERMINATION OF SEVEN ANIONS IN WATER LETTUCE GROWN IN A NATURAL UNPOLLUTED HABITAT BY ION CHROMATOGRAPHY	426
<b>Milica Zdravković, V. Grekulović, N. Štrbac, J. Suljagić, I. Marković, M. Gorgievski, M. Marković</b>	
THE COPPER CORROSION IN CHLORIDE MEDIUM WITH ADDITION OF BLACKBERRY LEAF EXTRACT	432
<b>Hazardous materials and green technologies</b>	
<b>Aleksandra A. Jovanović, M. R. Elferjane, M. Gnjatović, B. Bugarski, A. Marinković</b>	
PHOSPHOLIPID LIPOSOMES AS A CARRIER FOR ALOE VERA WASTE EXTRACT	438

<b>Aleksandra A. Jovanović, M. R. Elferjane, M. Milošević, M. Gnjatović, A. Marinković</b>	
Vaccinium myrtillus LEAF WASTE EXTRACTS WITH NATURAL DEEP EUTECTIC SOLVENT	444
<b>Danijela Kovačević, N. Đorđević, S. Glišić, B. Vlahović, V. B. Pavlović</b>	
MORPHOLOGICAL INVESTIGATION OF PVDF/MAGNETITE@NC/BaTiO <sub>3</sub> SEMI-SPHERICAL COMPOSITE MATERIALS FOR OIL REMOVAL	450
<b>Branislava Savić, D. Aćimović, M. Ječmenica Dučić, M. Simić, D. Vasić Anićijević, T. Brdarić</b>	
DEGRADATION OF PHENOL AND SUBSTITUTED PHENOLS: INFLUENCE OF APPLIED POTENTIAL	456
<b>Marija Ječmenica Dučić, D. Aćimović, B. Savić, M. Simić, A. Krstić, D. Vasić Anićijević, T. Brdarić</b>	
DEGRADATION OF DYES MIXTURE BY ELECTROCHEMICAL OXIDATION USING STAINLESS STEEL ELECTRODE	460
<b>Marija Simić, D. Aćimović, B. Savić, M. Ječmenica Dučić, I. Perović, D. Vasić Anićijević, T. Brdarić</b>	
THE OXYGEN EVOLUTION REACTION AT TIN DIOXIDE-CARBON-BASED ELECTRODES	465
<b>Drita Abazi Bajrami, M. Marinkovski, K. Lisichkov, S. Kuvendziev</b>	
OPTIMIZATION OF THE <i>Helichrysum arenarium</i> EXTRACT OBTAINED WITH ULTRASOUND-ASSISTED EXTRACTION	469
<b>Berina Sejdinović</b>	
VIBRATION ISOLATION	475
<b>Uroš Stamenković, I. Marković</b>	
THE INFLUENCE OF AGEING ON THE THERMAL PROPERTIES AND MICROSTRUCTURE OF THE EN AW-6082 GREEN ALUMINIUM ALLOY	482
<b>Ljubiša Balanović, D. Manasijević, I. Marković, U. Stamenković, M. Petrić</b>	
MICROSTRUCTURAL AND THERMAL CHARACTERIZATION OF Bi-Sb-Sn ALLOYS FOR ECOLOGICAL APPLICATION	488
<b>Vladan Nedelkovski, S. Stanković, M. Radovanović, Ž. Tasić, S. Milić</b>	
OPTIMIZATION OF PHENOL ELECTROCHEMICAL OXIDATION USING MODIFIED Ti/SnO <sub>2</sub> -TYPE ANODES	494
<b>Aleksandar Cvetković, Ž. Tasić, M. Petrović Mihajlović, A. Simonović, M. Radovanović, M. Nujkić, M. Antonijević</b>	
INFLUENCE OF SUBSTITUTES ON THE EFFICIENCY OF ORGANIC CORROSION INHIBITORS	500

<b>Sonja Stanković, M. Nujkić, Ž. Tasić, D. Medić, A. Papludis, S. Milić</b>	
MODIFIED MEMBRANES WITH GRAPHENE OXIDE – REMOVAL OF DYES FROM WASTEWATER	506
<b>Human and ecological risk assessment</b>	
<b>Olga Kostić, D. Pavlović, M. Marković, Z. Miletić, N. Radulović, M. Mitrović, P. Pavlović</b>	
HUMAN HEALTH RISK ASSESSMENT OF PTE <sub>s</sub> IN ELECTROFILTER ASH AND CHRONOSEQUENCE FLY ASH FROM “TENT A” DISPOSAL SITES	512
<b>Agriculture: nutrition, organic food and health impacts</b>	
<b>Markola Saulić, V. Trajić, D. Stojićević, A. Stevanović, Z. Živković</b>	
EFFECT OF EXTRACT <i>Ecklonia maxima</i> ON CONDITION OF AGRICULTURAL CROPS	519
<b>Metodi Mladenov</b>	
SUITABILITY OF THE SOILS IN THE MUNICIPALITY OF KOVACHEVTSI, BULGARIA FOR GROWING ON EINKORN WHEAT ( <i>Triticum monococcum</i> )	524
<b>Gorica Cvijanović, V. Stepić, M. Bajagić, V. Cvijanović, J. Marinković, N. Đurić</b>	
INFLUENCE OF EFFECTIVE MICROORGANISMS ON THE BASIC PARAMETERS OF SOIL BIOGENICITY IN THE PRODUCTION OF WHEAT AND CORN	529
<b>Vojkan Miljković, R. Ljupković, M. Miljković</b>	
APPLICATION OF CLASSIC THIN LAYER CHROMATOGRAPHY METHOD FOR QUALITATIVE DETERMINATION OF SYNTHETIC FOOD COLORS	535
<b>Alternative energy: efficiency and environmental policy</b>	
<b>Snežana Brković, N. Zdolšek, I. Perović, G. Tasić, M. Seović, S. Mitrović, J. Georgijević</b>	
NOVEL CARBON MATERIAL FOR OER IN VARIOUS ELECTROLYTE SOLUTIONS	540
<b>Nikola Zdolšek, I. Perović, S. Brković, M. Seović, J. Georgijević, S. Mitrović, P. Laušević</b>	
THE EFFECT OF DIFFERENT TYPE OF ELECTROLYTES ON THE DISCHARGE CAPACITY OF Zn-AIR BATTERIES	545
<b>Jelena Georgijević, J. Milikić, N. Zdolšek, I. Perović, S. Brković, S. Mitrović, B. Šljukić</b>	
IRON, COBALT DUAL DOPED CARBON ELECTROCATALYST FOR EFFICIENT WATER SPLITTING	550

## Greenhouse effect and global climate change

- Tatjana Dimitrijević, G. Šekularac, M. Ratknić, M. Aksić**  
EFFECTS OF CLIMATE CHARACTERISTICS ON THE DIAMETER INCREMENT OF RED OAK IN THE CITY OF BELGRADE (SERBIA) 555
- Milica Blažić, T. Sekulić, V. Stupar, Z. Živković**  
GREENHOUSE EFFECT AND GLOBAL CLIMATE CHANGE – IMPACT ON AGRICULTURE 561
- Vojkan Miljković, I. Gajić, Lj. Nikolić**  
GLOBAL CLIMATE CHANGES: GREENHOUSE GASSES, CITIES AND PLASTICS 567

## Sustainable development and green economy

- Zlata Živković, M. Saulić, D. Stojićević, M. Jevtić, V. Stupar**  
ROLE OF NUTRIENTS IN CONTROLLING PLANT DISEASES AND PATHOPHYSIOLOGICAL ALTERATIONS IN PLANTS IN SUSTAINABLE AGRICULTURE. A REVIEW 572
- Zlata Živković, M. Saulić, D. Stojićević, M. Jevtić**  
THE WAY OF MANAGING PLANT DISEASES IN SUSTAINABLE AGRICULTURE 578
- Dragan Ugrinov, M. Nikolić**  
THE ROLE OF PLANTS IN BIOECONOMY AND CIRCULAR ECONOMY 584
- Vojkan Miljković, I. Gajić, Lj. Nikolić**  
AGRICULTURAL WASTE IN SUSTAINABLE AGRICULTURE 589
- Ana Radojević, J. Milosavljević, S. Šerbula, T. Kalinović, J. Kalinović**  
RECYCLING OF Li-ION BATTERIES FROM THE END-OF-LIFE VEHICLES: OPPORTUNITY OR LIABILITY IN THE FUTURE? 593

## Environmental biology

- Vladimir Topalović, S. Matijašević, V. Savić, J. Nikolić, J. Stojanović, S. Zildžović, S. Grujić**  
CRYSTALLIZATION CHARACTERISTICS OF BIOACTIVE POLYPHOSPHATE GLASSES 599

## Environmental and material flow management

- Isidora Berežni, T. Marinković, B. Batinić**  
ASSESSING THE COMPOSITION OF MUNICIPAL SOLID WASTE IN ŠID 605

**Ivan Bracanović, A. Krstić, A. Kalijadis**

SYNTHESIS AND CHARACTERISATION OF CARBON NANOMATERIAL USING HYDROTHERMAL CARBONISATION METHOD

612

**Hamid Husić, S. Čerčić, V. Aganović**

RETROSPECTIVE OF THE PLANNED ACTIVITIES FOR THE REHABILITATION OF THE DAMAGED AREA OF THE FORMER SURFACE MINE ČUBRIĆ

617

### Student Section

**Students: Ana Smiljković, Isidora Sujić (Serbia)**

**Mentor: Maja Nujkić (Serbia)**

ENVIRONMENTAL AND HEALTH RISK OF CO<sub>2</sub> IN INDOOR ENVIRONMENTS

624

**Student: Avram Kovačević (Serbia)**

**Mentor: Uroš Stamenković (Serbia)**

ANTHROPOGENIC MERCURY IN THE ENVIRONMENT: GLOBAL EMISSIONS AND RECYCLING POSSIBILITIES

626

**Student: Petar Milanović (Serbia)**

**Mentors: Uroš Stamenković, Avram Kovačević (Serbia)**

THE INFLUENCE OF COOLING RATE ON MECHANICAL PROPERTIES AND MICROSTRUCTURE OF C45 CARBON STEEL

628

**Student: Milica Denić (Serbia)**

**Mentor: Jelena Kalinović (Serbia)**

AIR POLLUTION WITH CARCINOGENIC SUBSTANCES

630

**Student: Gordan Mišić (Serbia)**

**Mentor: Jelena Kalinović (Serbia)**

ACID RAIN AND SMOG – CHEMICAL REACTIONS

632

**Student: Milica Denić (Serbia)**

**Mentor: Ana Radojević (Serbia)**

MEDICAL WASTE MANAGEMENT

634

**Student: Gordan Mišić (Serbia)**

**Mentor: Ana Radojević (Serbia)**

ENVIRONMENTAL POLLUTION BY PET PACKAGING

636

**Student: Marija Stanković (Serbia)**

**Mentor: Ana Simonović (Serbia)**

COPPER CORROSION IN ARTIFICIAL ACID RAIN SOLUTION IN PRESENCE OF 5-PHENYL-1-TETRAZOLE

638



## POTENTIAL ENVIRONMENT POLLUTANT – INTERMEDIATE PRODUCT OF THE STEEL PRODUCTION PROCESS

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### **Abstract**

*As an intermediate product of the steel production process using an electric arc furnace, electric arc furnace dust (EAF dust) occurs. The resulting intermediate product of steel production is considered hazardous industrial solid waste in many countries of the world, given that it contains a large number of heavy metals that can reach the environment due to the action of atmospheric influences if it is not adequately disposed of. In this paper, the physico-chemical characterization of the EAF dust originating from a steel plant in the Republic of Serbia was performed, and Toxicity Characteristic Leaching Procedure (TCLP test) and Leachability Procedure (LP test) were performed in order to define the impact of this material on the environment and human health. The chemical analysis of the tested sample of the EAF dust showed a zinc content of 32.44%, iron – 18.92%, lead – 1.39%, cadmium – 0.04%, chromium – 0.25% and a lower content of a large number of other elements. The results of the LP test showed an increased chloride content in the leaching eluate, above the permitted limits, even for waste disposal at a hazardous waste landfill. In the TCLP eluate, the content of zinc, cadmium and lead are above the permitted limits, thus the sample shows toxic characteristics and danger to the environment and human health. In order to environmental and human health protection, it is necessary to do the treatment of this type of material before disposal at the landfill.*

**Keywords:** EAF dust, environmental protection, TCLP test, LP test.

### **INTRODUCTION**

During the steel production using electric arc furnaces, at a process temperature of 1600°C, during the melting of a batch of scrap iron, some elements evaporate. Volatile elements, together with a part of solid particles, go as a gas phase to the gas purification system, during which one of the intermediate products of this process – electric arc furnace dust (EAF dust) is formed [1,2].

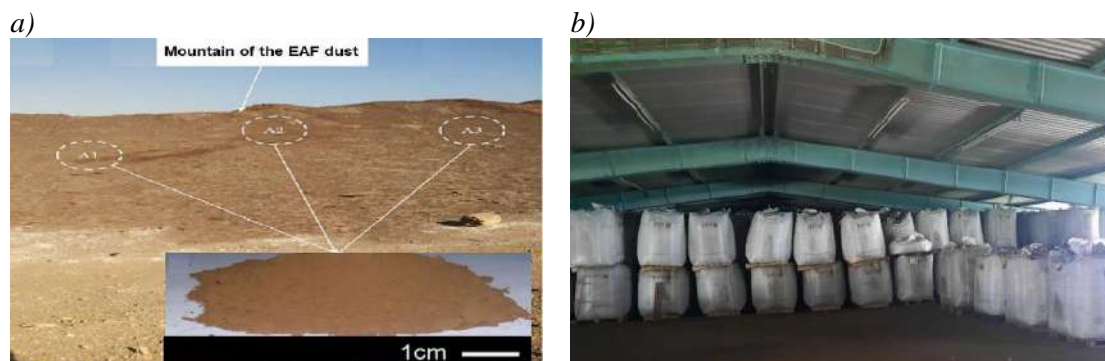
During the production of 1 ton of raw steel, about 10–20 kg of red-brown EAF dust is generated [1,3–9]. Due to the presence of heavy metals in the EAF dust, it is considered officially hazardous industrial solid waste in many countries [3,6–8,10–13].

In this paper, the physico-chemical characterization of the EAF dust originating from a steel plant in the Republic of Serbia was performed, and its toxicity characteristics and leachability were examined in terms of defining its impact on the environment and human health after disposal in a landfill.

## POTENTIAL ENVIRONMENTAL POLLUTION WITH EAF DUST

The potential pollution of this type of waste consists in the possibility of leaching of heavy metals, such as: Zn, Cu, Ni, Cd, Cr, Pb, F and Cl, etc., which are in its composition [14]. Inadequate disposal of the EAF dust has a negative impact on the environment [7]. There is still a large amount of EAF dust in the world, the treatment of which should be carried out as soon as possible, and which is accumulated around steel plants or in landfills of this material. Disposal method of the EAF dust is very important. If the EAF dust is inadequately disposed of, and in inappropriate landfills, due to the action of atmospheric influences, self-leaching of heavy metals from the EAF dust may occur. It is necessary to ensure that when the EAF dust is disposed in hazardous waste landfills, it must be protected from rain, in order to prevent the formation of polluted leachate, which could contaminate the surrounding areas [14].

Figure 1a shows a "mountain" of the EAF dust generated from steel production in Egypt [1]. The figure represents a typical inadequate way of disposing of this type of waste, given that the waste is exposed to atmospheric influences. Also, considering that the EAF dust is a material with very fine particles that can spread in the air, this kind of exposure to it due to the action of the wind makes it possible [1,14]. A more adequate way of disposal of the EAF dust from steel production in the Republic of Serbia is shown in Figure 1b. The EAF dust is packed in jumbo bags and stored under a canopy at the landfill around of the steel plant, in the production process of which it is generated.



**Figure 1** Method of disposal of the EAF dust in the world and in our country a) landfill in Egypt [1]; b) landfill in the Republic of Serbia

In order to environmental protection and human health protection from the negative impact of this type of hazardous waste, it is necessary to carry out its treatment in accordance with the legislation of the country where it is located. Before applying any treatment of electric arc furnace dust, it is necessary to carry out its detailed characterization.

### Physico-chemical characterization

The results of the physical characterization of the initial representative sample of the EAF dust are as follows: moisture – 0.36%, pH value of the sample – 11.42, density – 4.351 g/cm<sup>3</sup> and bulk mass – 654 kg/m<sup>3</sup>.

The chemical composition of a representative EAF dust sample is presented in the Table 1.

**Table 1** Chemical composition of a representative EAF dust sample [15]

Element	Content, %	Element	Content, %
Zn	32.44	Ca	3.85
Fe	18.92	Co	0.0017
Sn	0.037	Pb	1.39
S	0.51	Ni	0.036
Mo	<0.005	P	0.15
Mn	1.81	Mg	0.93
Si	1.34	Sb	0.022
Cr	0.25	Al	0.73
As	0.0041	K	0.87
Cd	0.04	Na	1.28
Cl	2.85	Hg	0.0001
Bi	0.013	Ag	0.00604
Cu	0.19	Au	0.00004

## LABORATORY INVESTIGATIONS OF THE IMPACT ON THE ENVIRONMENT AND HUMAN HEALTH

According to the Rulebook on categories, investigation and classification of waste (Official Gazette of RS 93/2019, 39/2021), with regard to the impact on the environment and human health after its disposal, toxicity and leachability tests of the material were performed on a representative sample of the EAF dust. Laboratory tests were carried out according to accredited standard methods: SRPS EN 12457-2 for testing material leachability, and EPA 1311 for testing material toxicity characteristics.

### Leachability Procedure (LP test)

The results of the leachability test (LP test) of a representative EAF dust sample according to the SRPS EN 12457-2:2008 standard are presented in Table 2 [15].

Due to the increased chloride content in the leaching eluate (leaching solution) above the permitted limits, even for waste disposal at a hazardous waste landfill, based on the leachability test results, the EAF dust sample was categorized as hazardous waste in terms of disposal. These results indicate that the EAF dust must undergo pretreatment before final disposal.

**Table 2** Leachability test results for the representative EAF dust sample

Parameter	Measured value	Reference value for non-hazardous waste <sup>a</sup>	Reference value for hazardous waste <sup>b</sup>
pH	11.31	6–13 <sup>c</sup>	-
Conductivity, $\mu\text{S}\cdot\text{cm}^{-1}$	8288	-	-
Content of dry matter, $\text{mg}\cdot\text{kg}^{-1}$			

Table 2 continued

Elements	Measured value	Reference value for non-hazardous waste <sup>a</sup>	Reference value for hazardous waste <sup>b</sup>
Zn	3.00	50	200
As	<0.20	2	25
Cu	<0.05	50	100
Sb	<0.50	0.7	5
Cd	<0.08	1	5
Mo	4.70	10	30
Ni	<0.07	10	40
Se	<0.33	0.5	7
Pb	10.00	10	50
Cr	<0.05	10	70
V	<0.08	200	-
Hg	<0.005	0.2	2
Ba	2.60	100	300
Ag	<0.05	50	-
Cl <sup>-</sup>	<b>30900</b>	<b>15000</b>	<b>25000</b>
F <sup>-</sup>	36.30	150	500
SO <sub>4</sub> <sup>2-</sup>	7400	20000	50000
Phenol index	0.24	1000	-

<sup>a,b</sup>Annex 10 of the Rulebook on categories, investigation and classification of waste (Official Gazette of RS 93/2019, 39/2021), Article 2, Parameters for testing waste and leachate from non-hazardous waste landfills<sup>a</sup> and hazardous waste<sup>b</sup>. Ambient temperature 21°C, humidity 52 %, pressure 970 hPa.

<sup>c</sup>Reference value for pH according to the Rulebook 93/2019, 39/2021 Annex 7, H15-Waste that has the property of producing another substance in any way after disposal, e.g. leachate that has any of the following characteristics (H1-H14), is 6–13. The measured pH value is within the allowable range.

### Toxicity Characteristic Leaching Procedure (TCLP test)

Table 3 [15] presents the results of the toxic leaching characteristic test (TCLP test) (EPA 1311) of a representative sample of the EAF dust intended for disposal.

The obtained results of the TCLP test show that the EAF dust sample, due to the increased content of zinc, cadmium and lead in the TCLP eluate (leaching solution), which are above the permitted prescribed limits, showed toxic characteristics. This type of hazardous waste requires additional attention and the application of appropriate treatment in order to environmental protection and human health protection.

The treatment of this type of hazardous waste can be performed by hydrometallurgical, pyrometallurgical or combined procedures [1,5,6,10,15]. Considering the highest content of zinc in the EAF dust, compared to all other elements, there is a possibility of its recovery by some of the mentioned procedures, which would also make it possible to make a profit. Apart from the application of the appropriate treatment of the EAF dust, primarily in order to protect the environment from the negative impact of hazardous waste, it is observed that this material can represent a secondary raw material for recovery of zinc.

Table 3 TCLP test results of a representative EAF dust sample

Elements	Measured value, mg·dm <sup>-3</sup>	Reference value for non-hazardous waste <sup>a</sup> , mg·dm <sup>-3</sup>	Elements	Measured value, mg·dm <sup>-3</sup>	Reference value for non-hazardous waste <sup>a</sup> , mg·dm <sup>-3</sup>
V	<0.008	24	Ag	<0.005	5
Cr	<0.005	5	<b>Cd</b>	<b>13.88</b>	<b>1</b>
Ni	0.068	20	Ba	0.880	100
Cu	0.050	25	Hg	<0.0005	0.20
<b>Zn</b>	<b>2690.67</b>	<b>250</b>	<b>Pb</b>	<b>61.16</b>	<b>5</b>
Ar	<0.020	5	Mo	<0.007	350
Se	<0.033	1	Sb	<0.050	15

<sup>a</sup>Annex 10 of the Rulebook on categories, investigation and classification of waste (Official Gazette of RS 93/2019, 39/2021), Article 1, Parameters for testing the toxic characteristics of waste intended for disposal.

## CONCLUSION

Dust from the electric arc furnace (EAF dust) is generated as an intermediate product of the steel production process by melting secondary raw materials in an electric arc furnace. Due to the fact that the EAF dust contains a large number of heavy metals that can enter the environment due to the action of atmospheric influences, this material is considered hazardous industrial solid waste in many countries of the world. Chemical analysis of a representative EAF dust sample, originating from the Republic of Serbia, determined the content of the following elements: zinc – 32.44%, iron – 18.92%, lead – 1.39%, cadmium – 0.04%, chromium - 0.25% and lower content of a large number of other elements. Laboratory tests of toxicity characteristics (TCLP test) and leachability (LP test) were also performed on a representative EAF dust sample. The results of the TCLP test showed that the content of zinc, cadmium and lead are above the permitted prescribed limits, on the basis of which it can be concluded that the sample shows toxic characteristics and danger to the environment and human health. The results of the LP test showed increased chloride content in the eluate for leaching, above the permitted limits, even for waste disposal at the hazardous waste landfill. In order to protect the environment and human health, it is necessary to do the treatment of this type of material before its disposal in a landfill. The treatment can be performed using hydrometallurgical, pyrometallurgical or combined procedures. Apart from the application of appropriate treatment of the EAF dust, primarily in order to protect the environment from the negative impact of this hazardous waste, this material can also be used as a secondary raw material for zinc recovery, and gaining adequate economic profit.

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