



THE ACADEMY OF APPLIED
TECHNICAL STUDIES
BELGRADE



INTERNATIONAL SCIENTIFIC
AND PROFESSIONAL CONFERENCE
POLITEHNIKA 2023

CONFERENCE PROCEEDINGS

Belgrade, 15th December 2023



INTERNATIONAL SCIENTIFIC
AND PROFESSIONAL CONFERENCE
POLITEHNIKA 2023

CONFERENCE PROCEEDINGS

Belgrade, 15th December 2023

PUBLISHER

The Academy of Applied Technical Studies Belgrade
Katarine Ambrozić 3, Belgrade
www.atssb.edu.rs

FOR THE PUBLISHER

Marina Stamenović, PhD, Professor of Applied Studies

THEMATIC SECTION EDITORS

Olivera Jovanović, PhD
Svetozar Sofijanić, PhD
Aleksandra Nastasić, PhD
Nenad Đorđević, PhD
Ana Cvijanović, MA
Biljana Ranković Plazinić, PhD
Marko Jauković, PhD
Andrijana Đurđević, PhD
Tatjana Sekulić, PhD
Goran Zajić, PhD

TECHNICAL PREPARATION AND COVER DESIGN

The Academy of Applied Technical Studies Belgrade, Organizing Committee

DESIGN OF THE CONFERENCE LOGO

Dušan Borović

PRINT

The Academy of Applied Technical Studies Belgrade, Katarine Ambrozić 3, Belgrade

THE CIRCULATION

400



THE ACADEMY OF APPLIED
TECHNICAL STUDIES
BELGRADE



CONFERENCE SCOPES:

**ENVIRONMENT AND
SUSTAINABLE DEVELOPMENT**

**OCCUPATIONAL HEALTH
AND SAFETY AND FIRE SAFETY**

SMART MANAGEMENT SYSTEMS

**GRAPHIC ENGINEERING
DESIGN**

TRAFFIC ENGINEERING

BIOTECHNOLOGY AND HEALTHCARE

MECHANICAL ENGINEERING

**ECOTOURISM AND
RURAL DEVELOPMENT**

MECHATRONICS

THE CONFERENCE IS SUPPORTED BY:

The Ministry of Education, Republic of Serbia
The Ministry of Environmental Protection, Republic of Serbia
The Ministry of European Integration, Republic of Serbia
Directorate for Occupational Safety and Health, Republic of Serbia
The Office for Dual Education and National Qualifications Framework
Conference of Academies for Applied Studies in Serbia
Chamber of Commerce of Serbia
Chamber of Commerce of Belgrade
Institute for Standardization of Serbia
The Association of Belgrade Architects
The City of Požarevac
Tourist Organization of The City of Požarevac



THE ACADEMY OF APPLIED
TECHNICAL STUDIES
BELGRADE

ORGANIZER

The Academy of Applied Technical Studies Belgrade
Katarine Ambrozić 3, Belgrade
www.atssb.edu.rs

INTERNATIONAL SCIENTIFIC COMMITTEE

assoc. prof. Filip Kokalj, PhD, Faculty of Mechanical Engineering, Maribor, Slovenia, president

prof. Andrea Matta, PhD, Politecnico di Milano, Milano, Italy

prof. Boštjan Pokorny, PhD, dean of Faculty of Environmental Protection, Velenje, Slovenia

Prof. Ute Margarete Meyer, PhD, dean of Faculty of Architecture and Energy Engineering, Biberach, Germany

prof. Alessandro Gasparetto, PhD, Polytechnic Department of Engineering and Architecture, Udine, Italy

prof. Niko Samec, PhD, Faculty of Mechanical Engineering, Maribor, Slovenia

prof. Ana Paula Vale, PhD, Polytechnic Institute of Viana do Castelo, Viana do Castelo, Portugal

prof. Michalis Koniordos, PhD, University of West Attica, Athens, Greece

prof. Anka Trajkovska Petkoska, PhD, Faculty of Technology and Technical Sciences-Veles, North Macedonia

prof. Yury Kuznetsov, PhD, Orel State Agrarian University, Orel, Russia

prof. Mohhamed-Salah Aggoune, PhD, University of Batna 2, Algeria

prof. Ilija Nasov, PhD, Faculty of Technology and Technical Sciences-Veles, North Macedonia

prof. Tihomir Latinović, PhD, Faculty of Informational Technologies, Vitez University, Travnik, Bosnia and Herzegovina

prof. Driss Nehari, PhD, Ain Timouchen University, Algeria

prof. Viliana Vasileva, PhD, Agricultural Academy, Institute of Forage Crops, Pleven, Bulgaria

prof. Dorin Camen, PhD, Faculty of Engineering and Applied Technologies, Timisoara, Romania

prof. Elizabeta Miskoska-Milevska, PhD, Faculty of Agricultural Sciences and Food, Skopje, North Macedonia

assoc. prof. Srećko Stopić, PhD, Aachen University, Germany

assoc. prof. Ezzaldeen Edwan, PhD, Palestine Technical College – Deir El-Balah

assoc. prof. Plamen Zahariev, PhD, University of Ruse "Angel Kanchev", Ruse, Bulgaria

Muharrem Hilmi Aksoy, PhD, Konya Technical University, Konya, Turkey

Gregor Rak, MSc, Vocational College of Traffic and Transport Maribor, Slovenia

Darko Ljubić, PhD, McMaster University, Hamilton, Canada

Dániel Kovács, Hungarian Museum of Architecture and Monuments Protection Documentation Center, Budapest, Hungary

Nataša Kraljević, LL.M., University Mediterranean, Podgorica, Montenegro

prof. Petar Uskoković, PhD, dean of Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

prof. Srđan Glišović, PhD, dean of Faculty of Occupational Safety, University of Niš, Serbia

prof. Goran Čpajak, dean of Faculty of Applied Arts, University of Arts in Belgrade, Serbia

Branko Savić, PhD, president of Conference of Academies of Applied Studies Serbia

prof. Aleksandar Petrović, PhD, Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Serbia

prof. Aleksandar Jovović, PhD, Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Serbia

assoc. prof. Biserka Vukomanović Đurđević, PhD, Military Medical Academy, Belgrade, Serbia

Marina Stamenović, PhD, president of Academy of Applied Technical Studies Belgrade, Belgrade, Serbia

PROGRAM COMMITTEE

prof. Slaviša Putić, PhD, Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia, president

prof. Vojkan Lučanin, PhD, Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Serbia

prof. Aleksandar Marinković, PhD, Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

prof. Evica Stojiljković, PhD, Faculty of Occupational Safety, University of Niš, Niš, Serbia

prof. Momir Prašević, PhD, Faculty of Occupational Safety, University of Niš, Niš, Serbia

prof. Tanja Manojlović, MA, Faculty of Applied Arts, University of Arts in Belgrade, Belgrade, Serbia

assoc. prof. Saša Drmanić, PhD, Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

assoc. prof. Milivoj Pavlović, PhD, Faculty of Fine Arts, University of Arts in Belgrade, Belgrade, Serbia

assoc. prof. Zoran Štirbanović, PhD, Technical Faculty, University of Belgrade, Bor, Serbia

doc. Vladimir Pavičević, PhD, Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

doc. Katarina Trivunac, PhD, Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

doc. Maja Đolić, PhD, Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

Danica Stojiljković, PhD, University of Belgrade – Institute for Multidisciplinary Research, Belgrade, Serbia

Aleksandra Patarić, PhD, Institute for Technology of Nuclear and Other Mineral Raw Materials, Belgrade, Serbia

Ivana Jovičić, PhD, Institute of Pesticides and Environmental Protection, Belgrade, Serbia

Dejan Blagojević, PhD, Academy of Technical Educational Vocational Studies, Niš, Serbia

prof. Dragan Šešlija, PhD, Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia

Valentina Mladenović, PhD, Technical College of Applied Sciences, Zrenjanin, Serbia

Dominik Brkić, PhD, Academy of Applied Technical Studies Belgrade, Belgrade, Serbia

Aleksandra Nastasić, PhD, Academy of Applied Technical Studies Belgrade, Belgrade, Serbia

Tatjana Marinković, PhD, Academy of Applied Technical Studies Belgrade, Belgrade, Serbia

Predrag Drobnjak, PhD, Academy of Applied Technical Studies Belgrade, Belgrade, Serbia

Goran Zajić, PhD, Academy of Applied Technical Studies Belgrade, Belgrade, Serbia

ORGANIZING COMMITTEE

Ana Popović, PhD, president

Nebojša Ćurčić, MSc, deputy president

Predrag Maksić, PhD

Dragana Gardašević, PhD

Dragana Kuprešanin, PhD Arts

Aleksandra Božić, PhD

Zlata Živković, PhD

Tatjana Sekulić, PhD

Novak Milošević, MSc

Aleksandra Janićijević, MSc

Ana Cvijanović, MA

Natalija Gaković, MA

Aleksandra Božović, MSc

Milan Marković, MSc

Svetlana Živanović, MSc

REVIEWERS

Svetozar Sofijanić, PhD, Marta Trninić, PhD, Radenko Rajić, PhD, Nikola Tanasić, PhD, Goran Đorđević, PhD, Daniela Ristić, PhD, Nebojša Ćurčić, MSc, Jasmina Rajić, PhD, Filip Kokalj, PhD, Ana Popović, PhD, Olivera Jovanović, PhD, Aleksandra Božić, PhD, Vesna Alivojvodić, MSc, Dominik Brkić, PhD, Darko Ljubić, PhD, Nataša Radić, MSc, Tatjana Sekulić, PhD, Aleksandar Stevanović, PhD, Saša Marković, PhD, Nada Ratković Kovačević, PhD, Aleksandar Petković, MSc, Đorđe Đurđević, PhD, Anka Trajkovska Petkoska, PhD, Ilija Nasov, PhD, Marko Jauković, PhD, Ivana Matić Bujagić, PhD, Aleksandar Ivković, MSc, Aleksandra Nastasić, PhD, Koviljka Banjević, PhD, Dragana Gardašević, PhD, Ana Slavković, PhD, Zorica Baroš, PhD, Dragana Đurić, PhD, Aleksandra Pavlović, PhD, Jasmina Đurašković, PhD, Bosiljka Srebro, PhD, Brankica Pažun, PhD, Željko Ranković, PhD, Biljana Ranković Plazinić, PhD, Svetlana Živanović, Dejan Jovanov, PhD, Marko Pavlović, PhD, Vladanka Stupar, PhD, Goran Zajić, PhD, Nenad Đorđević, PhD, Žolt Kovač, PhDArts, Ljubomir Maširević, PhD, Željko Zdravković, PhDArts, Jelena Zdravković, MA, Predrag Maksić, PhD, Dragana Kuprešanin, PhDArts, Jelena Drobac, PhDArts, Oliver Tomić, PhD, Duško Radaković, MSc, Natalija Gaković, MA, Sandra DePalo, MA, Ana Cvijanović, MA, Rajko Radosavljević, PhDArts, Muharrem Hilmi Aksay, PhD, Zlata Živković, PhD, Darko Stojićević, PhD, Michallis Koniordos, PhD, Tatjana Marinković, PhD, Marina Stamenović, PhD, Plamen Zahariev, PhD, Bogdan Marković, PhD, Andrijana Đurđević, PhD, Danijela Živojinović, PhD, Saša Marković, PhD, Đorđe Dihovični, PhD, Dragana Velimirović, PhD, Bojan Ivljanin, PhD



FOREWORD

The International Scientific and Professional Conference POLITEHNIKA 2023 represents the seventh edition of the POLITEHNIKA scientific and professional events, occurring biannually since its inaugural event in 2011. POLITEHNIKA 2023 upholds a distinguished tradition and commitment to integrating higher education and practical application across a diverse spectrum of disciplines represented by defined thematic scopes.

Organized with the patronage of the Ministry of Education of the Republic of Serbia, the Ministry of Environmental Protection of the Republic of Serbia, the Ministry of European Integration of the Republic of Serbia, the Directorate for Occupational Safety and Health, the Office for Dual Education and National Qualifications Framework, the Conference of Academies of Applied Studies in Serbia, the Chamber of Commerce of Serbia, the Chamber of Commerce of Belgrade, the Institute for Standardization of Serbia, the Association of Belgrade Architects, the City of Požarevac and the Tourist Organization of the City of Požarevac, POLITEHNIKA 2023 stands as a collaborative platform at the intersection of academia, governmental institutions and industry.

This year heralds a notable progression with its international status and the incorporation of 10 conference scopes. Expanding beyond the thematic domains featured in previous events, the Conference now encompasses Environment and Sustainable Development, Occupational Safety and Health and Fire Safety, Smart Management Systems, Graphic Engineering, Design, Traffic Engineering, Biotechnology and Healthcare, Mechanical Engineering, Ecotourism and Rural development, and Mechatronics. By engaging experts, emerging professionals, and practitioners from these domains, the conference unifies fields of study programs of the Academy of Applied Technical Studies Belgrade. The thematic scopes, coupled with the structure of the compiled papers in this Proceedings, exhibit a rich diversity and multidisciplinary approach, fundamentally contributing to a holistic examination and resolution of societal and scientific challenges.

Comprising over 220 peer-reviewed contributions, the Proceedings represent a substantial intellectual asset, aligning with the conference's overarching objective of fostering the exchange of knowledge, research findings, and professional experiences among experts from industry, research institutions, and higher education establishments.

The Proceedings of the International Scientific and Professional Conference POLITEHNIKA 2023 serve as a comprehensive snapshot of the current landscape within the thematic realms of the conference, offering both insights and directives for ongoing scientific and professional development. Moreover, they proffer concrete solutions to practical challenges grounded in contemporary trends and pertinent insights.

The Academy of Applied Technical Studies Belgrade extends its sincere appreciation to all conference supporters whose financial contributions played a pivotal role in its successful realization. Special acknowledgment is reserved for the authors of the papers, whose diligence and eagerness to present their work to a wider audience, alongside the reviewers and members of the International Scientific Committee, Program Committee and Organizational Committee, have collectively contributed to the triumph of the International Scientific and Professional Conference POLITEHNIKA 2023.

Belgrade, December 2023
EDITORS



ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

INVITED PAPERS

Srećko Stopić, PhD, Bernd Friedrich, PhD, Process Metallurgy and Metal Recycling, RWTH Aachen University, Germany

Advances in understanding of a role of unit metallurgical operations for recycling

Svetlana Grujić, PhD, Faculty of Technology and Metallurgy, University of Belgrade

Emerging pollutants in the environment: contamination of the Danube river basin in Serbia

Marija Nikolić, PhD, Faculty of Technology and Metallurgy, University of Belgrade

Biodegradable polyesters – from ecology to medicine

DESIGN

INVITED PAPER

Jelena Ristić Trajković, PhD, Faculty of Architecture, University of Belgrade

Society, Ecology and Design Education: Transformative Learning for Future Sustainable and Healthy Environments

MECHANICAL ENGINEERING

INVITED PAPERS

Tamara Bajc, PhD, Faculty of Mechanical Engineering, University of Belgrade

Energy savings and CO₂ emission reduction potential through the existing building renovation

Marko S. Jarić, PhD, Innovation Centre of Faculty of Mechanical Engineering in Belgrade

Analysis of remediation of horizontal cylindrical tank for oil storage

ECOTURISAM AND RURAL DEVELOPMENT

INVITED LECTURES

Marko Perić, PhD, Faculty of Tourism and Hospitality Management, University of Rijeka, Croatia

Challenges of sustainable tourism: Example of Croatia

Snežana Štetić, PhD, Balkan Network of Tourism Experts, Igor Trišić, PhD, Faculty of Geography, University of Belgrade

Selective forms of tourism and sustainable development of rural tourist destinations

INVITED PAPERS

Radomir Stojanović, PhD, Western Serbia Academy of Applied Studies

Education as a pillar of sustainable agritourism in Serbia

Jelena Premović, PhD, Faculty of Economics, University of Priština & Faculty of Economics and Engineering, University Business Academy in Novi Sad

Cultural heritage as a generator of sustainable development of tourism in local communities in the countries of the Western Balkans

Vladimir Živanović, Nevena Majstorović, Zlatibor Tourism Organization, Zlatibor

Analysis of the real number of tourist overnights based on the estimation of water consumption in Zlatibor

MECHATRONICS

INVITED PAPER

Andrea Matta, PhD, Dept. of Mechanical Engineering, Politecnico di Milano, Italy Mohsen Jafari, PhD, Dept. of Industrial and Systems Engineering, Rutgers University, USA

Towards a theory of digital twins: fundamental definition

TABLE OF CONTENTS

SCOPE 1. ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

Srećko Stopić, Bernd Friedrich <i>Advances in understanding of a role of unit metallurgical operations for recycling</i>	26
Svetlana Grujić <i>Emerging pollutants in the environment: contamination of the Danube river basin in Serbia</i>	32
Marija Nikolić <i>Biodegradable polyesters – from ecology to medicine</i>	38
Alessandro Gasparetto, Stefano Grimaz <i>The ESPeRT project: a “polytechnic” strategic plan focused on sustainability</i>	44
Ana Stojković, Miodrag Stanisavljević, Ivan Krstić, Nenad Krstić, Dragan Đorđević <i>Physical-chemical characterization of waste glass of general use</i>	50
Ljiljana Tolić Stojadinović, Svetlana Grujić, Nikolina Antić, Tatjana Đurkić <i>Impact of wastewater antibiotics on river water quality in Belgrade area</i>	54
Nataša Karić, Marija Vukčević, Marina Maletić, Mirjana Ristić, Aleksandra Perić Grujić, Katarina Trivunac <i>Removal of organic and inorganic pollutants from aqueous solutions using starch-diatomaceous earth adsorbent</i>	60
Nataša Karić, Marina Maletić, Sara Živojinović, Marija Vukčević, Milena Milošević, Katarina Trivunac, Aleksandra Perić Grujić <i>Alkali modification of fly ash for adsorption of selected dyes</i>	66
Katarina Popović, Davor Antanasijević, Jelena Antanasijević, Viktor Pocajt <i>Carbon footprint of bio-based and recycled plastic materials</i>	71
Katarina Popović, Davor Antanasijević, Jelena Antanasijević, Viktor Pocajt <i>Application of machine learning for the simulations and modeling in environmental science</i>	77
Jasmina Bašić, Danijela Pecarski, Dragana Dragaš Milovanović, Slavica Krsmanović, Daka Tešić <i>Air quality according PM concentration in the city of Belgrade in September 2023</i>	83
Jelena Vesković, Milica Lučić, Slavica Ražić, Ivana Deršek-Timotić, Andrijana Miletić, Maja Đolić, Antonije Onjia <i>Multivariate analysis of the Morava river plain groundwater</i>	89
Eleonora Gvozdić, Ivana Matić Bujagić, Tatjana Đurkić, Svetlana Grujić <i>Ecological risk assessment of aspartame and neotame in river sediments</i>	95
Mirjana Ocokoljić, Djurdja Petrov <i>Impact of urban heat island on butterfly-bush (<i>buddleja davidii franch.</i>)</i>	100
Mirjana Ocokoljić, Djurdja Petrov, Dragan Vujičić <i>Effects of urbanisation on <i>simplicarpos orbiculatus moench</i> in the green infrastructure of Belgrade</i>	106
Anja Bubik, Katrin Školnik Škrabe <i>Chemical variability of personal care and cosmetic products</i>	112
Miloš Tošović <i>Technical-technological disasters, risk assessment and environmental security</i>	118

Radule Tošović	124
<i>Economic considerations of the relationship of national income, mineral reserves and environmental accounting</i>	
Slavica Krsmanović, Danijela Pecarski, Jasmina Bašić	130
<i>Quality of swimming pool water and hygiene</i>	
Jelena D. Lukić, Latinka J. Slavković-Beškoski, Katarina V. Trivunac, Antonije E. Onjia	134
<i>Analysis of heavy metal(loid)s in coal fly ash leachate by inductively coupled plasma optical emission spectrometry</i>	
Andrijana Miletić, Antonije Onjia	139
<i>Analysis of carbon monoxide in ambient air using passive sensors</i>	
Ivana Trajković, Milica Sentić, Slobodan Cvetković, Andrijana Miletić, Antonije Onjia	145
<i>Analysis of BTEX in sediments by purge-and-trap gas chromatography-mass spectrometry</i>	
Saša Marković, Darja Žarković	150
<i>Economic instruments in the function of environmental protection</i>	
Jelena Milosavljević, Snežana Šerbula, Tanja Kalinović, Jelena Kalinović, Ana Radojević	156
<i>Overview of air pollution in the city of Bor during the period of 2020–2022</i>	
Milan Trumić, Vladimir Nikolić, Mirjana Marić, Jelena Janković	162
<i>Mining solid waste around Bor, yesterday, today, tomorrow</i>	
Danijela M. Jašin, Ljubica Lazić Vulićević, Valentina Mladenović, Aleksandar Rajić	167
<i>The solution for reusing non-recyclable plastic-based materials</i>	
Filip Živković, Milica Stojković, Maja Đolić, Mirjana Čujić	173
<i>Elemental analysis of rare earth elements in coal fly ash from thermal power plants in the Republic of Serbia</i>	
Darja Žarković, Saša Marković	177
<i>Sustainable production in cardboard industry</i>	
Marija Prosheva, Jadranka Blazhevskaja Gilev	182
<i>Sensors for ammonia detection based on carbon nanofiller</i>	
Marija Prosheva, Jadranka Blazhevskaja Gilev	188
<i>Investigation of the UV stability of lignin/polymer composites</i>	
Ana Momčilović, Marta Trninić	193
<i>A comprehensive analysis: offshore renewable energy methodologies, benefits, and limitations</i>	
Danijela Đurić Mijović, Danijela Milanović, Jelena Savić, Miloš Nedeljković, Dušan Randelović	199
<i>Wind comfort design based on building position</i>	
Zaga Trišović, Tomislav Trišović, Ana Virginia Socalici, Corneliu Banesa Birtok	204
<i>Innovative system for electrochemical active chlorine production in coaxial and cabinet-type reactors</i>	
Đorđe Karić, Aleksandra Sretenović-Dobrić	209
<i>Analysis of energy-saving measures in residential buildings connected to district heating systems using information technology</i>	
Bosiljka Srebro, Stefan Milojević, Miljan Adamović	214
<i>Environmental accounting education for sustainable development: a comprehensive overview</i>	
Vladana Đurđević, Aleksandra Janićijević, Dominik Brkić, Ana Popović, Marina Stamenović, Aleksandra Božić	219
<i>Validation of the ICP-OES method for determining the elemental composition of water</i>	
Vladana Đurđević, Jelena Pavlović, Bojan Obradović, Ana Popović, Marina Stamenović, Aleksandra Božić	225
<i>Proficiency testing as a tool for quality control of laboratory test results in environmental pollution analysis</i>	

Radmila Marković, Zoran Stevanović, Zoran Štirbanović, Vojka Gardić, Renata Kovačević, Vesna Marjanović, Jelena Petrović <i>Monitoring of the surface water quality in copper mining and metallurgy operation areas in Bor</i>	231
Biljana Angjusheva, Ildiko Merta, Emilja Fidancevski <i>Sustainable synergy: alkali-activated coal fly ash and CDW in sustainable construction</i>	237
Vaishnavi Inamdar, Ana Popović <i>Global ESG perspectives and the changing world of 2023: a sustainability odyssey</i>	242
Nikola Stojković, Dominik Brkić, Svetlana Čupić, Aleksandra Božić, Sladjana Glišić, Vladana Đurđević <i>Determination of polychlorinated biphenyls in waste oil</i>	247
Dejan Vasić, Vladana Đurđević, Marina Stamenović, Aleksandra Božić, Aleksandra Janićijević, Dominik Brkić <i>Determination of PAHS in medical waste</i>	252
Vesna Alivojvodić, Aleksandra Vučinić <i>EU taxonomy as a framework for a functioning circular economy</i>	256
Milica Marković, Ana Momčilović, Maja Stanković <i>Environmental concerns of lithium battery disposal</i>	261

STUDENTS PAPER

Miloš Kovačević, Nataša Radić <i>Air pollution caused by modern-day armed conflict</i>	266
Danijela Jeremić, Daniela Ristić <i>Influence of “Stubo-Rovni” dam on climate change in the city of Valjevo</i>	272

SCOPE 2. OCCUPATIONAL HEALTH AND SAFETY AND FIRE SAFETY

Marta Trninić <i>Application of 3D random e-glass fiber composites in construction hardhat design</i>	278
Drago Pupavac, Ljudevit Krpan, Josip Knežević <i>Cost-benefit analysis in employee health and safety protection</i>	284
Svetozar Sofijanić, Vladan Pantović, Željko Ognjanović <i>Centralized information system for monitoring workplace injuries</i>	290
Dragan Živanić, Nikola Ilanković <i>Safety concerning cableways</i>	296
Dragan Živanić, Nikola Ilanković <i>Basic safety measures for chain conveyors</i>	302
Nataša Ćirović, Ana Petrović, Marija Burilo <i>Testing of microclimate and physical harms in the sawmills</i>	308
Ana Petrović, Nataša Ćirović <i>Noise level investigation in production process</i>	314
Vesna Marjanović, Jelena Jelisić <i>Comparative analysis of risk assessment in the field of construction</i>	320
Saša Kuzmanović <i>Analysis of assessed professional risks at the workplace of forklift drivers in the Logo company with comparative risk assessment methodologies and reference to the current law</i>	325

Marija Mićanović, Tanja Radović <i>Implementation of strategies for the development of critical thinking in English language teaching among the students of the Occupational safety and health study program at the Academy of applied technical studies Belgrade</i>	331
Tanja Radović, Marija Mićanović <i>Business communication obstacles in English language in occupational health and safety education</i>	335
Radenko Rajić, Ivan Arandjelović, Nikola Tanasić <i>A novel tabular method for estimation of waterflow rate at the hydrant nozzle</i>	338
Goran Đorđević, Martina Petković, Ljubinko Rakonjac, Marko Tomić, Anita Klikovac <i>Selection and use of mechanized equipment for extinguishing forest fires in order to increase efficiency - methodological approach</i>	342
Darko Marković, Nebojša Ćurčić <i>Prevention of occupational risks in transport and installation of concrete prestressed T-girders on project Iverak-Lajkovac</i>	350

STUDENTS PAPER

Milena Andrejević <i>“Near miss” events in the TPS Zemun reconstruction project: a research and analysis</i>	357
Maja Đikić, Novak Milošević <i>Research and analysis of professional stress issues among employees in security roles</i>	363
Lazar Milićević, Novak Milošević <i>The impact analysis of stress accumulated outside the workplace on the occupational safety and health of employees in Institute of Nuclear Sciences „VINČA”</i>	368
Jelena Tintor, Jasmina Rajić, Igor Babić <i>Researching the harmful effects of cooling liquid on employees</i>	374
Jelena Tintor, Jasmina Rajić, Igor Babić <i>Employee safety during plastic deformation metal processing</i>	380
Milica Marković <i>Chemical hazards in horticulture from the aspect of occupational safety and health</i>	385
Marijana Drakulić <i>Potentially explosive atmospheres in flour production</i>	391

SCOPE 3. SMART MANAGEMENT SYSTEMS

Radoslav Raković <i>Information security management standard and personal data protection – practical experiences</i>	398
Miloš Jelić, Ana Aksentijević Jelić <i>Deficiencies and advancement in organizational strategic decision - making</i>	404
Igor Milić <i>Civil protection management model at the local government level</i>	410
Dragan Zlatković, Kostadinka Stojanović, Mirjana Tomić, Nebojša Denić <i>Artificial Intelligence as support for quality 4.0: a review of current applications and future directions</i>	415
Koviljka Banjević, Jovana Femić <i>Adult education in Serbia and countries in the region</i>	421

Dragana Gardašević, Dragana Rošulj, Mina Radišić, Koviljka Banjević <i>Application of the Pareto analysis in quality control</i>	428
Aleksandra Nastasić, Dragana Rošulj, Koviljka Banjević, Aleksandra Pavlović <i>The influence of digital transformation on customer perception</i>	433
Ana Maksimović <i>The effectiveness of environmental social and governance due diligence in driving sustainable outcomes in the outdoor apparel industry</i>	439
Aleksandra Pavlović, Aleksandra Nastasić, Andrea Ivanišević <i>QMS and EMS implementation in Serbian organizations – a driving factor for sustainable development</i>	445
Ana Maksimović <i>Socially responsible chains: investigating the social implications of supply chain due diligence in corporate sustainability</i>	453
Aleksandra Pavlović, Aleksandra Nastasić, Predrag Drobnjak, Ana Langović Milićević, Andrea Ivanišević, Ivana Katić <i>PPP projects and economic growth in Serbia</i>	459
Marija Marčetić, Danijela Misoloska, Bojan Kocić <i>The threats and opportunities in modern forwarding business</i>	467
Jelena Pavlović, Dragica Stanković <i>Contemporary approach to leadership, management, knowledge and innovation</i>	472
Marko Pavlović, Ana Petrović, Đorđe Pavlović <i>Study on the attitudes of electronic banking users in Serbia</i>	477
Jelena Pavlović, Dragica Stanković <i>New technologies, labor market and human resources</i>	484
Zorica Baroš <i>The impact of the kelvin redefinition within the SI System on the improvement of temperature measurement technologies</i>	490
Ana Đokić, Hana Stefanović <i>Analysis and visualisation of COVID 19 data set in Python programming language</i>	496
Sanja Pavlović, Dejan Crnoglavac, Aleksandar Starčević <i>Examining the role of drones as educational tools: an practical teaching example in enhancing learning experiences in STEM education</i>	501
Đorđe Dihovični, Dragan Kreculj, Nada Ratković Kovačević <i>Experiences in teaching and mastering materials in WEB applications in vocational education</i>	507
Marko Pavlović, Ana Petrović, Đorđe Pavlović <i>E-learning: study on students' opinions</i>	513

SCOPE 4. GRAPHIC ENGINEERING

Aleksa Milovanović, Tomáš Babinský, Aleksandar Sedmak, Miloš Milošević <i>Printing parameter impact on PLA material fracture toughness results</i>	520
Bojan Banjanin, Neda Milić Keresteš, Jelena Kerac, Rastko Milošević, Savka Adamović <i>Applications of real-time rendering game engine in education through practices and initiatives</i>	526
Slađana Glišić, Predrag Živković, Aleksandra Janićijević <i>Examination of the possibility of dyeing printing papers with plant extracts</i>	532

SCOPE 5. DESIGN

Jelena Ristić Trajković <i>Society, Ecology and Design Education: Transformative Learning for Future Sustainable and Healthy Environments</i>	539
Biljana Pejić, Bojana Škorc <i>The effects of style on an aesthetic assessment of design</i>	545
Biljana Pejić, Bojana Škorc <i>Familiarity as aesthetic category in design</i>	551
Dragica Nikodinović <i>Analogous principle as an added value in graphic design in the post-industrial era</i>	557
Dušanka Komnenić <i>Design as a form of communication, deconstructive approach to design</i>	563
Duško Trifunović, Anamarija Vartebedijan <i>Graphic design by Miodrag Vartebedijan Varta, Vatra's graphic mark in Yugoslavian and world design</i>	567
Emmanouil Tzimitzimis, Alexandros Papoutsis, Nikolaos Koumartzis, Konstantinos Tsongas, Dimitrios Tzetzis <i>Utilizing parametric computer-aided design and modal analysis for the redesigning of Anglo-Saxon medieval lyres</i>	573
Emmanouil Tzimitzimis, Dimitrios Sagris, Constantinos David, Dimitrios Tzetzis <i>Evaluating the influence of infill pattern and density in fused filament fabrication 3D printing technology through multimedia data analysis business communication</i>	579
Ivana Desnica <i>Leather recycling in the context of Haute Couture</i>	585
Jelena Jocić, Maida Gruden <i>Design and education: traditional and online environment</i>	590
Jelena Zdravković <i>Design fashion and the industry: The context of the emergence of fashion and ready-to-wear clothing production</i>	596
Katarina Nikolić, Danica Glodović, Aljoša Ninković <i>Design, ideology and propaganda</i>	602
Ljubomir Maširević <i>The social significance of video games</i>	607
Maja Milinić Bogdanović <i>Interdisciplinaryness of sustainable design</i>	613
Marija Mićanović, Tanja Radović <i>Motivation for English language learning among the students of the design study programs at the Academy of Applied Technical Studies Belgrade</i>	619
Natalija Gaković <i>Does Frank Lloyd Wright's Fallingwater House represent a precursor to sustainable design?</i>	623
Natalija Gaković <i>Children without parental care in social protection institutions – Park of support design</i>	628
Natalija Đukić <i>Analysis of the spatial organization of a modern apartment in Belgrade, case study New Dorcol</i>	634

Predrag Maksić <i>Design to the measure of marketing</i>	639
Sandra DePalo <i>The experiance and percepton of the light colour in the spatial contex</i>	644
Suzana Polić <i>Techno - praxeological opinions about design: views from perspective of protection of cultural heritage</i>	650
Suzana Polić <i>Visuality, method and Laban's orthography: one parallel</i>	656
Željko Zdravković <i>Bioart and our creative biotechnological future</i>	662

STUDENTS PAPERS

Jelica Živković <i>Use of gold color in interior design</i>	668
Sara Todorović <i>Use of coper color in interior design</i>	674

SCOPE 6. TRAFFIC ENGINEERING

Dejan Jovanov, Daniel Pavleski, Kosta Jovanov <i>Road safety management capacity review – use of Tailor-made checklists</i>	680
Željko Ranković, Nemanja Deretić, Aleksandra Obradović <i>Consequences of traffic accidents in the Republic of Serbia in the period from 2013 to 2022 with proposed measures to reduce fatal consequences</i>	686
Aleksandra Obradović, Dalibor Pešić, Željko Ranković <i>Statistical analysis of traffic accidents on state roads in the work zone on the territory of the Republic of Serbia for the period from 2014 to 2021</i>	692
Lazar Kocić, Aleksandra Obradović <i>Analysis of safety of cyclists in traffic in the city of Smederevo from 2018 to 2022</i>	697
Biljana Ranković Plazinić, Aleksandra Obradović <i>The length of dilemma zone at signalized intersections</i>	702
Kristina Milić <i>Role of the rescue coordination centre in land in case of aircraft accidents</i>	708
Dejan Kožović, Dragan Đurđević <i>Trends of artificial intelligence in aviation: cyber security of ADS-B system</i>	713
Saša Marković, Svetozar Sofijanić <i>The importance of low-cost and differentiation strategies for the business of traffic companies</i>	719
Svetlana Živanović <i>Analysis of the competitiveness of logistics providers in the area of the Western Balkan countries</i>	725
Svetlana Živanović, Gordana Radivojević, Milorad Kilibarda <i>Selection of logistics provider in the field of e-commerce</i>	730
Class “Tecnico Superiore della Logistica per la GDO” biennio 2022-24, ITS Logistica Puglia Bari, Michele Minenna, Nataša Gojković Bukvić <i>Market research aimed towards the analysis of the possibility of launching an operational Start up in the field of LCL (Less Than Container Load) transport at the ports of Bari and/or Taranto (Italy)</i>	736

Miloš Nikolić, Ivana Jovanović, Milica Šelmić 742
A survey on the vehicle routing problem with occasional drivers and its variants

Marina Milovanović Arandelović 748
Application of probability and stochastic analysis to traffic improvement

STUDENT PAPER

Jelena Vajović, Marina Stevanović 754
Improvement of traffic safety on the chosen intersection in the town of Pancevo

SCOPE 7. BIOTECHNOLOGY AND HEALTHCARE

Tatjana Sekulić, Zlata Živković, Marija Perkunić 761
Biological control as an evolving technology in pest management

Zlata Živković, Goran Nestorović, Milan Vasić, Darko Stojićević, Tatjana Sekulić, Markola Saulić 767
Smart farming and long-term sustainability

Zlata Živković 772
Varroa destructor, the parasitic mite of Apis mellifera: a review

Dorin Dumitru Camen, Mădălina Elena Dumitrașc, Maria Mihaela Moatăr 777
Research on the photosynthesis rate in the species Salvia Officinalis in vitro and in vivo

Aleksandar Stevanović, Vera Popović, Milica Jevtić, Jelena Bošković 783
Application of new technologies for adaptation to climate changes in agricultural production

Aleksandar Stevanović, Goran Nestorović, Vera Popović 789
Information systems in organic agriculture - a review

Vladanka Stupar, Darko Stojićević, Aleksandar Stevanović 795
Raising the vineyard - pruning and agrotechnical measures: a review

Markola Saulić, Darko Stojićević 801
Crop modelling: a new tools for crop production

Darko Stojićević, Markola Saulić 805
Basic concepts of ANN model and its application in agricultural research

Milica Blažić 810
Applications of molecular markers in animal genetics and breeding: a review

Milica Blažić, Markola Saulić, Vladanka Stupar 816
Precision agriculture technologies and methodologies used to crop yield prediction – a review

Vladanka Stupar, Darko Stojićević, Aleksandar Stevanović, Milan Vasić 822
Implementation of robotic technologies on apple pruning: a review.

Milica Jevtic, Vladanka Stupar, Milica Blažić 828
Precision agriculture in vegetable farming

Milica Jevtić, Goran Nestorović, Milan Vasić, Darko Stojićević 833
The agricultural smart systems

Milan Vasić, Zlata Živković, Goran Nestorović, Darko Stojićević 838
Drive units in robots for controlled pesticide application

Dubravka Mandušić, Lucija Blašković 844
Deep learning in fruit detection

Dobriła Randelović, Svetlana Bogdanović, Ivana Zlatković, Dragana Stanisavljević <i>Chemical properties and microbiological quality control of frozen plum fruit</i>	847
Aleksandra Stojićević, Tatjana Marinković, Aleksandar Stevanović, Miloš Purić <i>Application of medicinal herbs and spices as a food additive – challenges and limitations</i>	852
Milica Sentić, Ivana Trajković, Ivana Deršek-Timotić, Slobodan Cvetković, Zoran Stojanović, Antonije Onjia <i>Polycyclic aromatic hydrocarbons in medicinal herbs: analytical method development</i>	856
Jana Klopcevska, Zoran Kavrakovski, Marija Srbinoska, Vesna Rafajlovska <i>Nanoemulsions of pumpkin seed oil with turmeric extract</i>	861
Jana Klopcevska, Zoran Kavrakovski, Marija Srbinoska, Vesna Rafajlovska <i>Formulations of carboxymethyl cellulose-based emulgels with turmeric extract</i>	867
Maja Nujkić, Žaklina Tasić, Sonja Stanković, Dragana Medić, Snežana Milić, Vladan Nedelkovski <i>Potential application of mullein leaf as biosorbent for efficient biosorption of Cu(II) ions from synthetic solutions</i>	873
Višnja Sikimić, Slavica Čabrilo, Nada Jelić <i>Possibilities of production of a new functional product - mayonnaise with reduced fat content</i>	878
Miloš Purić, Aleksandra Stojićević <i>Utilization of apple pomace to obtain functional bakery and confectionery products</i>	884
Slavica Čabrilo, Višnja Sikimić, Miloš Purić <i>Alternative packaging in wine packaging technology</i>	889
Jasmina Rajić, Tanja Petrović, Dragana Mihajlović <i>Potential migration of phthalates from different polymers into food</i>	894
Marko Jauković, Tatjana Marinković, Aleksandar Stevanović, Svetozar Sofijanić <i>Food labelling – monitoring of allergen info in bakery retail stores</i>	900
Veroslava Kocić, Dušica Ćirković, Dragana Stanisavljević, Dobriła Randelović, Milica Stojanović, Jelica Lazić Saković, Aleksandar Veličković <i>The Influence of Raw Materials and the Production Process on the Quality of Rosé Wine</i>	904
Danka Mitrović, Nikolina Živković, Jelena Pavlović, Marko Jauković <i>Occurrence of ochratoxin a in wine in Serbia in 2022</i>	910
Anja Vuksan, Jelena Pavlović, Marina Stamenović, Marko Jauković <i>Aflatoxin M1 levels in milk in Serbia in 2022</i>	914
Danijela Pecarski, Dubravka Marinović, Dragana Dragaš Milovanović, Svetlana Karić <i>Adverse effects of pesticides on public health</i>	918
Milica Lučić, Ivana Sredović Ignjatović, Steva Lević, Jelena Lukić, Antonije Onjia <i>Exposure to potentially toxic elements due to consumption of Capsicum annuum in different parts of Serbia</i>	924
Milica Ivanović, Gordana Stefanović, Aleksandra Janković, Sandra Stanković <i>Identification of the optimal co-substrate for co-composting with grape pomace by using multiple criteria analysis</i>	930
Dragan Marinkovic, Tatjana Marinkovic, Aleksandra Jelic <i>Perspectives and challenges in cognitive enhancement based on the neurotechnology approach</i>	936
Snežana Knežević, Tamara Gajić, Dragan Vukolić, Miloš Zrnić, Slavica Đorđević <i>Prescribing wellness in primary care: integrating health and healthcare</i>	942
Snežana Knežević, Tamara Gajić, Dragan Vukolić, Miloš Zrnić, Slavica Đorđević <i>Lifestyle medicine: empowering health through behavior modifications</i>	948

Aleksandra Vracaric, Zeljko Karganovic, Slavka Mitricevic, Ivanka Djuricic <i>Complications of pertussis infection in neonate: a case report</i>	954
Vuk Aleksić, Radmila Aleksić <i>Sport related injuries in Brazilian jiu jitsu</i>	957

SCOPE 8. MECHANICAL ENGINEERING

Tamara Bajc <i>Energy savings and CO₂ emission reduction potential through the existing building renovation</i>	964
Marko S. Jarić <i>Analysis of remediation of horizontal cylindrical tank for oil storage</i>	970
Kuznetsov Yu. A., Kolomeichenko A.V., Logachev V. N., Kravchenko I. N., Kalashnikova L.V., Dobychin A., Yakovlev D.D., Gribakin A.A. <i>Study of porosity and oil capacity of coatings formed by electric arc metallization method</i>	978
Aggoune Mohammed-Salah, Bensedira Nouredine, Milles Abdessmad <i>Effect of the voltage and the magnetic field variations on the velocity field in a MH pump – simulation and experimental analysis</i>	983
Milan Milutinović, Goran Vasilic <i>The effects of tool wear on cutting forces during the turning operation of workpiece with coatings</i>	989
Đorđe Đurđević, Andrijana Đurđević, Nina Anđelić, Katarina Antić <i>Dynamic calculation of friction stir welding tools using the finite element method</i>	997
Dragana Velimirović, Milan Marković, Milan Velimirović <i>Critical review on the safety barriers from the structural and deformation parameters aspects</i>	1002
Elisaveta Doncheva, Aleksandra Krstevska, Marjan Djidrov, Filip Zdraveski, Trajche Velkovski <i>Wire-arc additive manufacturing: recent developments and potential</i>	1010
Andrijana Đurđević, Ljubiša Bučanović, Đorđe Djurdjević, Aleksandar Živković, Aleksandar Sedmak, Đorđe Dihovični <i>Production of a lap joint using friction stir welding and microhardness measurement using the Leeb method</i>	1016
Danijela Živojinović, Aleksandra Božović <i>Comparative analysis of the manufacturing time of a part on a CNC lathe obtained by calculation and simulation of machining using the CAD/CAM software system</i>	1021
Aleksandra Mitrović, Ivan Banjac <i>Optimization of FGD process in TPP Kostolac 'B'</i>	1026
Milan Marković, Dragana Velimirović, Andrijana Đurđević <i>Mathematical model of car rotating during overtaking in a left roadway curve</i>	1032
Misković Žarko, Zoran Stamenić, Jovana Antić, Radivoje Mitrović <i>The latest standards of rolling bearing testing</i>	1039
Murat Ispir, Ilker Goktepel, Muharrem H. Akso <i>Solar-powered farming: evaluating the viability of PV water pumping in Turkish agriculture</i>	1045
Bojan Ivljanin, Andrijana Đurđević, Đorđe Đurđević, Nada Ratković Kovačević <i>The phenomena of rigid and reverse waterhammer and their influence on maintenance of hydropower plants with Kaplan turbines</i>	1052
Miloš Mihailović, Miloš Božić, Tomislav Simonović, Aleksandra Božović <i>The influence of insulation thickness on investment and operational costs in heating systems with a heat pump in Serbia</i>	1058

Aleksandar Petkovic, Jovan Ilic, Ivan Bozic <i>Headwater level governing at small hydropower plants with open channel conveying system</i>	1063
Nenad Mitrovic, Zorana Golubovic, Aleksandra Mitrovic, Milan Travica, Isaak Trajkovic, Milos Milosevic, Aleksandar Petrovic <i>Application of 2D digital image correlation method on three-point bending in material testing</i>	1068
Dorđe Dihovični, Nada Ratković Kovačević, Andrijana Đurđević <i>Application of smart production systems in vocational education</i>	1072
Elisaveta Doncheva, Aleksandra Krstevska, Martin Petreski, Nikola Avramov, Jelena Djokikj <i>A study on the environmental and health impact of hazardous substances during welding</i>	1078
Stojko Biočanin, Milica Timotijević <i>Analysis of research on optimization models and algorithms for planning preventive maintenance of machine systems</i>	1084
Ana Maksimovic, Bojana Zečevic, Ljubica Milovic, Vujadin Aleksic <i>Experimental investigation on the use of JIC for a HSLA Steel Welded Joint</i>	1092
Dragan Šaler, Milan Grujić <i>Landing optimization of a small sounding rocket</i>	1097
Milanka Plavsic, Milenko Plavsic <i>System scaling renormalization problems in bio-thermodynamics: I) Yeast cell colony size scaling, as an opportune model</i>	1103
Aleksa Maljević, Milan Ignjatović <i>Influence of laminate stacking and fiber volume fraction on natural frequencies of composite kevlar 49 aramid – 3501 – 6 epoxy plates</i>	1109
Milivoje Filipović, Ivan Arandelović <i>Fire resistance of boiler room the building structure</i>	1115
Bojana Zečević, Ana Maksimović, Ljubica Milović, Vujadin Aleksić, Srdjan Bulatović <i>Effects of temperature on fatigue crack growth rate of a low carbon microalloyed steel</i>	1121
Goran Nestorović, Dragan Kreculj, Milan Vasić <i>Large-scale three-dimensional printers in Industry 4.0</i>	1125
Milan Travica, Nenad Mitrović, Aleksandar Petrović <i>Strain behavior analysis of steel S235JRH ring specimens</i>	1131
Nataša Trišović, Wei Li, Marko Gavrilović, Corneliu Banesa Birtok, Ognjen Ristić, Milica Milić, Radoslav Radulović, Zaga Trišović, Ana Virginia Socalici <i>Effects of changing design parameters</i>	1135
Stojko Biočanin, Milica Timotijević <i>Selected achievements in the research of the diagnostics of the lack of combustion in the engine and changes in the instantaneous angular velocity of the crankshaft</i>	1142
Neda M. Sokolović, Ivana Gavrilović-Grmuša, Nenad Šekularac <i>Panel shear properties of carbon fiber reinforced LVL board</i>	1149
Vule Reljić, Dragan Šešlija, Vladimir Jurošević, Valentina Mladenović <i>The influence of refrigerated dryers on the compressed air quality</i>	1155
Ivana Jevtić, Obrad Drakulović, Goran Mladenović, Miloš Milošević <i>Types of bee drinkers</i>	1161
Tamara Tešić, Milica Rančić, Danica Bajuk Bogdanović, Ivana Gavrilović Grmuša <i>Effect of tannin on increasing UF adhesive performance</i>	1165

SCOPE 9. ECOTOURISM AND RURAL DEVELOPMENT

Radomir Stojanović <i>Education as a pillar of sustainable agritourism in Serbia</i>	1172
Jelena Premović <i>Cultural heritage as a generator of sustainable development of tourism in local communities in the countries of the Western Balkans</i>	1177
Vladimir Živanović, Nevena Majstorović <i>Analysis of the real number of tourist overnights based on the estimation of water consumption in Zlatibor</i>	1182
Radomir Stojanović, Branko Radeljić <i>Safety and security standards and procedures of modern hotels</i>	1188
Slobodanka Stankov, Branko Radeljić <i>Guided tour as a type of animation in cultural tourism</i>	1194
Miloš Spasojević, Marija Popović, Jasmina Đurašković <i>Incentives for agriculture in the city of Belgrade</i>	1200
Jelena Basarić, Andrijana Golac Čubrilo <i>The role and significance of cultural-historical heritage in the development of cultural tourism – example of the Mileševa monastery</i>	1205
Zlata Živković, Markola Saulić, Vladanka Stupar, Ben Mladenović, Dragan Šaler <i>The potential for rural development in the Braničevo district through the tourist sights</i>	1212
Marija Perić, Ben Mladenović <i>Protection, development and management in a protected natural asset - analysis of the Petnička cave</i>	1218
Marija Perkunić, Tatjana Sekulić, Markola Saulić, Vladanka Stupar <i>The faunal diversity of memorial park Čačalica</i>	1224

STUDENT PAPER

Sara Ilanković <i>Cultural heritage of Italy</i>	1230
Sara Ilanković <i>Italian cinematography</i>	1235

SCOPE 10. MECHATRONICS

Andrea Matta, Mohsen Jafari <i>Towards a theory of digital twins: fundamental definitions</i>	1240
Đorđe Dihovični <i>An analysis of a process of decentralized control of a robot powered by a direct current motor</i>	1246
Milan Vasić, Mirko Blagojević, Goran Nestorović <i>Primary criteria for selecting gearboxes for axes of 6-axis industrial robots</i>	1250
Dragan Kreculj, Đorđe Dihovični, Nada Ratković Kovačević, Siniša Minić, Sanja Jevtić <i>MQTT protocol in the IoT</i>	1255

Srđan Barzut <i>The post-quantum cryptography and challenges in network security and Industry 4.0</i>	1261
Nebojša Andrijević, Vladan Radivojević, Duško Radaković, Dragan Milovanović, Suad Suljović <i>Conceptual model of a system for optimizing the temperature and humidity of honeybee hives using artificial intelligence</i>	1266
Goran Nestorović, Vladimir Petrović, Nebojša Andrijević, Nenad Petrović, Suad Suljović <i>The channel capacity of wireless communication system with L-branch SC combining in rayleigh short term fading and co-channel interference</i>	1270
Dragan Milovanović, Srđan Đorđević, Đorđe Miladinović, Nenad Petrović, Radiša Stefanović, Suad Suljović <i>The outage probability in system limited by Nakagami fading and co-channel interference for classification-based QoS estimation</i>	1276
Dragoslav Perić, Slobodan Obradović, Mirjana Nešić, Dragana Đurić <i>Computer devices and the Serbian language - interface and application</i>	1282



ANALYSIS OF CARBON MONOXIDE IN AMBIENT AIR USING PASSIVE SENSORS

*Andrijana Miletić¹, Faculty of Technology and Metallurgy, University of Belgrade
Antonije Onjia², Faculty of Technology and Metallurgy, University of Belgrade*

Abstract: *Air quality monitoring is necessary due to various pollutants that can have a harmful effect on human health. Carbon monoxide (CO) is a pollutant of concern because it is very toxic at low concentrations. It is an odorless and colorless gas that is very difficult to detect. In recent years, passive sensors have been widely used to analyze CO in ambient air. The CO sensor for commercial use must be stable during operation and have a linear and reproducible output over a long period. Hence, developing CO gas sensors with high sensitivity, selectivity, and stability is essential. This study compared three types of CO gas sensors: electrochemical, metal-oxide semiconductors, and colorimetric. Each of these sensors is characterized by specific advantages and disadvantages; therefore, their comparative analysis is presented, and their most important characteristics are emphasized.*

Keywords: air quality, electrochemical sensors, metal-oxide semiconductors, colorimetric sensors

1. INTRODUCTION

Rapid industrial development leads to the endangerment of the basic components of the environment: air, water, and soil. This type of pollution has a severe impact on people; therefore, the existence of environmental pollution control is of great importance [1]. Air pollution is a big problem worldwide, especially in cities with developed industries. Harmful substances come directly from anthropogenic or natural activities and can be formed later in the atmosphere through mutual interaction. Gases and particles that pollute the air can be hazardous and associated with various diseases. Air pollutants include CO, NO₂, NO, SO₂, NH₃, and many others [2]. Carbon monoxide (CO) is one of the most poisonous gases and is also called the silent killer because it is very toxic to humans [3]. It is colorless and odorless and can be produced from both natural and anthropogenic sources. This most often includes incomplete combustion of fossil fuels and exhaust gases from vehicles, as well as volcanic activity and wildfires [4]. Depending on the concentration of CO to which people are exposed, the health consequences can be minimal or even fatal [5]. By increasing the concentration of CO in the body, the amount of oxygen decreases because human blood has a much greater affinity for CO than for oxygen [1]. CO binds to hemoglobin in the blood and prevents it from transporting oxygen through the body. Some characteristic symptoms are headache, dizziness, and nausea, which occur at low concentrations of CO. At high concentrations, more serious organ damage occurs, and in fatal cases, even death [4]. Because the content of pollutants in the air directly affects people's health, it is extremely important to monitor air quality. Air monitoring is necessary to determine the source of pollution, assess exposure, and form a plan for air quality management to protect people from the harmful effects of polluting gases [6]. Monitoring the amount of dangerous gases in the air has drawn more attention recently as a way to control the environment, not only in industrial environments but also in workplaces and residences. Most researchers study pollutants such as CO, CO₂, NH₃, VOCs, SO₂, and others [1].

¹amiletic@tmf.bg.ac.rs

²onjia@tmf.bg.ac.rs

In the last few decades, various chemical sensors have been developed to detect various types of pollutants in various media [7,8]. Several types of popular sensors are piezoelectric [9], electrochemical [2], metal-oxide semiconductors [1], and colorimetric sensors [10]. For the analysis of pollutants in the air, various types of gas sensors that work on various principles have been developed to obtain fast but high-quality results [11]. Gas sensors are widely used for monitoring air quality in the environment, workplaces, living places, and industries [3]. Recently, gas sensors have been increasingly improved and developed to improve human safety and air quality. The main parameters of the gas sensor are sensor response, selectivity, sensitivity, limit of detection, energy consumption, operating temperature, and, of course, production costs [1]. Various devices are available for measuring CO concentration, but fast, portable, and selective sensors are still being developed [12]. So far, electrochemical sensors, metal-oxide semiconductors, and colorimetric sensors have been widely used [10]. The main goal of this study was to compare three various types of CO gas sensors. In recent years, using these sensors to analyze CO in ambient air has become a real challenge. Therefore, their comparative analysis is presented, and their most important characteristics are singled out.

2. PASSIVE SENSORS

2.1 Electrochemical sensors

Electrochemical sensors work on the principle of converting the concentration or partial pressure of the target gas into an electrical signal. These sensors can differ depending on what type of electrolyte they use: liquid, gel, or solid. However, using electrochemical sensors with a liquid electrolyte is increasingly common in practice. An electrochemical sensor consists of several parts: a working electrode, a counter electrode, a reference electrode, and an electrolyte. Figure 1 shows a schematic diagram of the electrochemical sensor. Electrodes can be made of various materials. The walls of the sensor housing must be made of a hydrophobic membrane that is permeable to gases and impermeable to liquids. This way, the amount of gas reaching the electrodes is controlled [4,13].

Determining CO is based on measuring the potential change when oxidation and reduction processes occur concurrently on the working and counter electrodes. Oxidation occurs when gases collide with the working electrode:



The process of oxygen reduction takes place on the counter electrode:



These two reactions lead to the flow of current. The generated current is related to the number of molecules that have been reduced, i.e., oxidized [4,13].

The measured value of electrochemical sensors can be affected by other substances in the air, and this phenomenon is called the crossing effect. During the crossing effect, the reduction/oxidation potential of undesirable substances is measured, and the result obtained in this way is not accurate. When the measured values are higher than the actual values, it is positive interference, while negative interference occurs when the read values are lower than the actual values. The operation of electrochemical sensors can be affected by the conditions under which the measurements are made [13]. Electrochemical sensors have a relatively fast response, low energy consumption, and are lightweight [11].

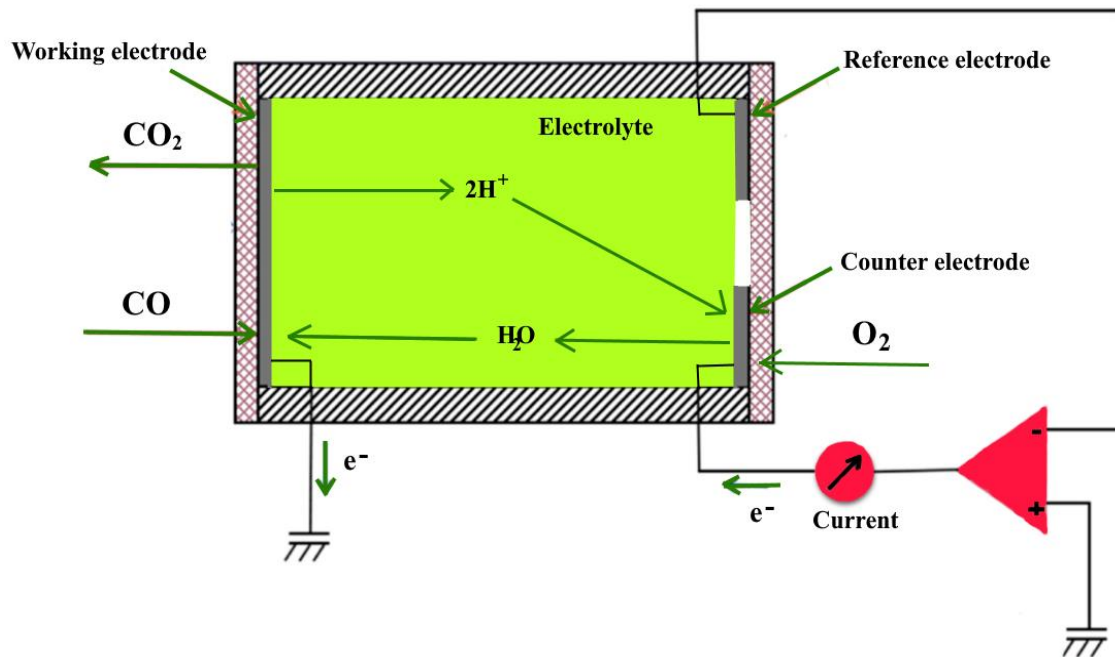


Figure 1. Schematic diagram of the electrochemical sensor

2.2 Metal-oxide semiconductors

When carbon monoxide comes into contact with a metal oxide semiconductor (MOS) gas sensor, a change in electrical conductivity or resistivity occurs. Based on that change, the target gas concentration is determined. Two types of MOS sensors used for CO detection, the n-type and the p-type, are shown in Table 1. Since not all oxides have the same properties, there are differences between semiconductors. Oxides such as SnO₂, ZnO, and TiO₂ are the most widely used because they have a good crystal structure, density, and lattice parameter, and they are the most studied for use in CO detection [1]. In addition to these three n-type conductors, Co₃O₄, the p-type semiconductor, gives good results in the determination of CO because it has a very high catalytic activity towards the oxidation of CO [14]. Metal oxides can be synthesized by various techniques such as hydrothermal, electrospinning, RF and DC sputtering, chemical vapor deposition (CVD), anodization, sol-gel, vapor phase transport, UV lithography, and many others [1].

Table 1. Various types of semiconductors for CO sensing

Metal-oxide	Type of the semiconductor	Reference
TiO ₂	n-type	[3]
SnO ₂	n-type	[15]
ZnO	n-type	[16]
Fe ₂ O ₃ or Fe ₃ O ₄	n-type	[17]
In ₂ O ₃	n-type	[18]
WO ₃	n-type	[19]
CuO	p-type	[1]
Cr ₂ O ₃	p-type	[20]
Co ₃ O ₄	p-type	[14]
NiO	p-type	[21]

MOS sensors detect CO based on the redox reaction between the determined gas and the sensing material. First, oxygen is adsorbed on the surface of metal oxides, creating a surface layer depleted of electrons. Depending on the types of MOS, there will be an electron-depletion layer in the n-type and a hole accumulation layer in the p-type. In the n-type, electrons are charge carriers, and in the p-type, holes are charge carriers. Therefore, due to the adsorption of oxygen molecules, the resistance

in the n-type is high and low in the p-type. Under the influence of the reducing gas, oxygen atoms are removed, and the trapped electron is transferred back to the sensing material, resulting in a decrease in the resistance in the n-type and an increase in the resistance in the p-type. Based on changes in resistance, MOS sensors detect CO gas [1,3]. MOS sensors are characterized by low cost, simplicity, high sensitivity, and low response time. The disadvantages are the high operating temperature, poor selectivity towards gases of the same type, and the fact that they are susceptible to environmental conditions. Currently, SnO₂ is the most efficient MOS material because it has excellent CO detection capabilities, especially at low concentrations [1,4].

2.3 Colorimetric sensors

The colorimetric determination of CO attracts attention due to its high sensitivity, simplicity, and selectivity. The reaction between the tested gas and the sensing probe is crucial when using colorimetric sensors. As a result of this reaction, a color change occurs. These sensing probes are a vital part of the sensor, and the operation of the CO sensor depends on these sensing probes. Chemicals in the probes act as catalysts for the reaction but also cause a color change. There are various types of sensing probes for CO determination. Most current colorimetric CO sensors are based on organic probes such as rhodium, iridium, and ruthenium complexes. Organic complexes of Pd are also used, and one example of a sensing probe contains palladium salts as a catalyst and molybdenum compounds as indicators. Although these probes have a fast response, high specificity, and high sensitivity for CO detection, their synthesis is complex [6,22].

Colorimetric sensors are characterized by their simplicity, rapid response, and low costs. However, their main disadvantage is the impossibility of continuously using a single sensor, especially when the resulting reaction is irreversible [23]. There are various attempts to overcome this shortcoming of colorimetric sensors. Lin et al. (2018) worked on a gradient-based colorimetric sensor, while Mo et al. (2023) developed a repeatable colorimetric system. The system is set to register changes in the colorimetric sensor signal, prevent the sensor from reaching saturation, and allow the sensor to fully regenerate before the subsequent measurement.

3. CONCLUSION

Air pollution from various contaminants is a problem worldwide, particularly in cities and urban areas where industry has grown. There must be enough monitoring to track the amount of contaminants in the air because air quality can significantly impact human health. Due to its unique characteristics and high toxicity, CO differs from other contaminants, making early identification and detection in ambient air crucial. As a result, carbon monoxide sensors aid in preventing excessive CO exposure; therefore, it is crucial to design CO gas sensors with high sensitivity, stability, and selectivity. There are several types of CO gas sensors, but the three most common types are electrochemical, metal-oxide semiconductor, and colorimetric sensors. These sensors have certain advantages regarding CO detection but also several drawbacks. Hence, researchers from all over the world are trying to overcome these disadvantages in order to enhance their performance. By comparing these three sensors, which are frequently used in the analysis of ambient air, their operating principles, advantages, and challenges associated with using them are highlighted. In this way, their comparative analysis was carried out. When synthesizing CO gas sensors, the main interests of researchers are in enhancing sensitivity, response time, selectivity and recovery time. Since the performance of the gas sensor depends on improving these key features, many researchers base their research on this. In addition, modern systems should undoubtedly be quick and affordable for the analysis of the target gas.

This research was supported by the Ministry of Science, Technological Development and Innovation, Republic of Serbia [grant number 451-03-47/2023-01/200135].

LITERATURE

- [1] Mahajan, S., Jagtap, S.: Metal-Oxide Semiconductors for Carbon Monoxide (CO) Gas Sensing: A Review, *Applied Materials Today*, Vol. 18 (2020), 100483, doi:10.1016/j.apmt.2019.100483.
- [2] Barhoum, A., Hamimed, S., Slimi, H., Othmani, A., Abdel-Haleem, F.M., Bechelany, M.: Modern Designs of Electrochemical Sensor Platforms for Environmental Analyses: Principles, Nanofabrication Opportunities, and Challenges, *Trends in Environmental Analytical Chemistry*, Vol. 38 (2023), e00199, doi:10.1016/j.teac.2023.e00199.
- [3] Uma, S., Shobana, M.K.: Metal Oxide Semiconductor Gas Sensors in Clinical Diagnosis and Environmental Monitoring, *Sensors and Actuators A: Physical*, Vol. 349 (2023), 114044, doi:10.1016/j.sna.2022.114044.
- [4] You, S., Li, G., Fan, Z., Li, X., Fu, L., Wu, W.: Nanotechnology-Assisted Sensors for the Detection of Carbon Monoxide: A Review, *International Journal of Electrochemical Science*, Vol. 18 (2023), 100314, doi:10.1016/j.ijoes.2023.100314.
- [5] Afshar-Mohajer, N.; Zuidema, C.; Sousan, S.; Hallett, L.; Tatum, M.; Rule, A.M.; Thomas, G.; Peters, T.M.; Koehler, K. Evaluation of Low-Cost Electro-Chemical Sensors for Environmental Monitoring of Ozone, Nitrogen Dioxide, and Carbon Monoxide, *Journal of Occupational and Environmental Hygiene*, Vol. 15 (2018), 87–98, doi:10.1080/15459624.2017.1388918.
- [6] Lin, C., Xian, X., Qin, X., Wang, D., Tsow, F., Forzani, E., Tao, N.: High Performance Colorimetric Carbon Monoxide Sensor for Continuous Personal Exposure Monitoring, *ACS Sensors*, Vol. 3 (2018), 327–333, doi:10.1021/acssensors.7b00722.
- [7] Tadić, T., Marković, B., Suručić, L., Nastasović, A., Onjia, A.: Application of sensors based on molecularly imprinted polymers for virus detection, *Ecologica*, Vol. 28 (2021), 543–550, doi:10.18485/ecologica.2021.28.104.8.
- [8] Nestic, A.R., Onjia, A., Ostojic, S.B., Micic, D.M., Velickovic, S.J., Antonovic, D.G.: Novel Biosensor Films Based on Chitosan, *Materials Letters*, Vol. 167 (2016), 47–49, doi:10.1016/j.matlet.2015.12.124.
- [9] Rajakovic, Lj., Onjia, A.: The Potential of Piezoelectric Sensors for Characterization of Activated Carbon Cloth Applied in Adsorption of Phenols from Air, In *Polymers in Sensors*, ACS Symposium Series, American Chemical Society: Washington, DC, 1998, Vol. 690, 168-173, doi: 10.1021/bk-1998-0690.ch015.
- [10] Lin, C., Zhu, Y., Yu, J., Qin, X., Xian, X., Tsow, F., Forzani, E.S., Wang, D., Tao, N.: Gradient-Based Colorimetric Sensors for Continuous Gas Monitoring, *Analytical Chemistry*, Vol. 90 (2018), 5375–5380, doi:10.1021/acs.analchem.8b00506.
- [11] Wei, P., Ning, Z., Ye, S., Sun, L., Yang, F., Wong, K., Westerdahl, D., Louie, P.: Impact Analysis of Temperature and Humidity Conditions on Electrochemical Sensor Response in Ambient Air Quality Monitoring, *Sensors*, Vol. 18 (2018), 59, doi:10.3390/s18020059.
- [12] Li, Z., Suslick, K.S.: Colorimetric Sensor Array for Monitoring CO and Ethylene, *Analytical Chemistry*, Vol. 91 (2019), 797–802, doi:10.1021/acs.analchem.8b04321.
- [13] Majder-Łopatka, M., Węsierski, T., Dmochowska, A., Salamonowicz, Z., Polańczyk, A.: The Influence of Hydrogen on the Indications of the Electrochemical Carbon Monoxide Sensors, *Sustainability*, Vol. 12 (2020), 14, doi:10.3390/su12010014.
- [14] Molavi, R., Sheikhi, M.H.: Low Temperature Carbon Monoxide Gas Sensor Based on Ag-Co₃O₄ Thick Film Nanocomposite, *Materials Letters*, Vol. 233 (2018), 74–77, doi:10.1016/j.matlet.2018.08.087.
- [15] Zhang, Y., Li, D., Qin, L., Zhao, P., Liu, F., Chuai, X., Sun, P., Liang, X., Gao, Y., Sun, Y., et al.: Preparation and Gas Sensing Properties of Hierarchical Leaf-like SnO₂ Materials, *Sensors and Actuators B: Chemical*, Vol. 255 (2018), 2944–2951, doi:10.1016/j.snb.2017.09.115.
- [16] Zeng, Y., Qiao, L., Bing, Y., Wen, M., Zou, B., Zheng, W., Zhang, T., Zou, G.: Development of Microstructure CO Sensor Based on Hierarchically Porous ZnO Nanosheet Thin Films, *Sensors and Actuators B: Chemical*, Vol. 173 (2012), 897–902, doi:10.1016/j.snb.2012.05.090.
- [17] Donarelli, M., Milan, R., Rigoni, F., Drera, G., Sangaletti, L., Ponzoni, A., Baratto, C., Sberveglieri, G., Comini, E.: Anomalous Gas Sensing Behaviors to Reducing Agents of Hydrothermally Grown α -Fe₂O₃ Nanorods, *Sensors and Actuators B: Chemical*, Vol. 273 (2018), 1237–1245, doi:10.1016/j.snb.2018.07.042.
- [18] Wang, X., Meng, Y., Li, G.-D., Zou, Y., Cao, Y., Zou, X.: UV-Assisted, Template-Free Synthesis of Ultrathin Nanosheet-Assembled Hollow Indium Oxide Microstructures for Effective Gaseous Formaldehyde Detection, *Sensors and Actuators B: Chemical*, Vol. 224 (2016), 559–567, doi:10.1016/j.snb.2015.10.100.

- [19] Long, H., Zeng, W., Zhang, H. Synthesis of WO₃ and Its Gas Sensing: A Review, *Journal of Material Science: Materials in Electronics*, Vol. 26 (2015), 4698–4707, doi:10.1007/s10854-015-2896-4.
- [20] Ding, C., Ma, Y., Lai, X., Yang, Q., Xue, P., Hu, F., Geng, W.: Ordered large-pore mesoporous Cr₂O₃ with ultrathin frameworks for formaldehyde sensing, *ACS Applied Materials and Interfaces*, Vol. 9 (2017), 18170–18177.
- [21] Liu, B., Wang, L., Ma, Y., Yuan, Y., Yang, J., Wang, M., Liu, J., Zhang, X., Ren, Y., Du, Q., et al.: Enhanced Gas-Sensing Properties and Sensing Mechanism of the Foam Structures Assembled from NiO Nanoflakes with Exposed {1 1 1} Facets, *Applied Surface Science*, Vol. 470 (2019), 596–606, doi:10.1016/j.apsusc.2018.11.129.
- [22] Duan, W., Wang, J., Peng, X., Cao, S., Shang, J., Qiu, Z., Lu, X., Zeng, J.: Rational Design of Trimetallic AgPt–Fe₃O₄ Nanozyme for Catalyst Poisoning-Mediated CO Colorimetric Detection, *Biosensors and Bioelectronics*, Vol. 223 (2023), 115022, doi:10.1016/j.bios.2022.115022.
- [23] Mo, M., Fu, B., Hota, P., Cay-Durgun, P., Wang, R., Cheng, E.H., Wiktor, P., Tsow, F., Thomas, L., Lind, M.L., et al.: Threshold-Responsive Colorimetric Sensing System for the Continuous Monitoring of Gases, *Sensors*, Vol. 23 (2023), 3496, doi:10.3390/s23073496.

=====
CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

6(082)(0.034.2)
5(082)(0.034.2)
331.45/.46(082)(0.034.2)
005(082)(0.034.2)

INTERNATIONAL Scientific and Professional Conference Politehnika (2023 ; Beograd)

Conference Proceedings [Електронски извор] / International Scientific and Professional Conference Politehnika 2023, Belgrade, 15th December 2023 ; [organizer] The Academy of Applied Technical Studies "Belgrade", Belgrade. - Belgrade : The Academy of Applied Technical Studies "Belgrade", 2023. - 1 USB fleš memorija ; 1 x 1 x 5 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 400. - Bibliografija uz svaki rad.

ISBN 978-86-7498-110-8

а) Техника -- Зборници б) Примењене науке -- Зборници в) Заштита на раду -- Зборници г) Менаџмент -- Зборници

COBISS.SR-ID 132801289

=====



THE ACADEMY OF APPLIED
TECHNICAL STUDIES
BELGRADE



skup-politehnika.atssb.edu.rs
atssb.edu.rs



9 788674 981108

ISBN-978-86-7498-110-8