



University of Novi Sad
Technical faculty "Mihajlo Pupin" Zrenjanin
Đure Đakovica bb,
23000, Zrenjanin, Serbia



XIV International Conference on
**INDUSTRIAL ENGINEERING AND
ENVIRONMENTAL PROTECTION**
IIZS 2024

On behalf of the Organizing Committee, I would like to invite you to participate in the International Conference on "INDUSTRIAL ENGINEERING AND ENVIRONMENTAL PROTECTION" - IIZS 2024. We are delighted to invite you to deliver an invited lecture during the event.

The Conference is an annual event organized jointly by departments of the Technical Faculty "Mihajlo Pupin" Zrenjanin and International partners.

The Conference will be held on October 4, 2024, at the Technical Faculty "Mihajlo Pupin" in Zrenjanin, Serbia. The opening ceremony is at 10 a.m. in the meeting room on the 2nd floor.

Any further information regarding the event can be found on our website:
<http://www.tfzr.uns.ac.rs/iizs/index.php>

We remain at your service for any further assistance you may need, and we look forward to welcoming you to Zrenjanin.

Welcome to IZZS 2024!

Warm Regards,

Asst. prof. Jasna Tolmač, Chairman of the Organizing Committee
University of Novi Sad
Technical Faculty "Mihajlo Pupin"
Zrenjanin, Serbia

e-mail: iizs@tfzr.rs

Jasna Tolmač

Signature



TECHNICAL FACULTY "MIHAJLO PUPIN" ZRENJANIN,
UNIVERSITY OF NOVI SAD,
REPUBLIC OF SERBIA



CONFERENCE AGENDA

Venue:

Technical Faculty "Mihajlo Pupin" Zrenjanin,
October, 3-4th, 2024.

Thursday, 03.10.2024.	
15.00 - 17.00h	Registration
19.00h	Welcoming cocktail
Friday, 04.10.2024.	
9.00 – 10.00h	<i>Registration</i>
10.00 – 10.30h <u>36</u>	<i>OPENING of the</i> <i>XIV International conference on Industrial Engineering and Environment Protection</i> Ph.D Milan Nikolić, Dean of the TF “Mihajlo Pupin” Ph.D Jasna Tolmač, President of the Organizing Committee
PLENARY SESSION	
10.30 -11.30h <u>35</u>	Chairs: Slavica Prvulović, Jasna Tolmač EXAMINATION OF THE SAMPLE PROPERTIES MADE BY THE ADDITIVE Mirko Karakašić EVALUATING MICROPOLLUTANTS IN THE DANUBE RIVER: ASSESSING CONCENTRATIONS AND ENVIRONMENTAL IMPACT Marija Perović
11.30 - 12.00h	<i>Coffee break</i>
12.00 - 13.00h	ORAL/POSTER PRESENTATION
SESSION 1 (Chairs: Ljiljana Radovanović, Borivoj Novaković)	
12.00 - 13.00h <u>36</u>	Mechanical Engineering Energetics and Process Technique Designing and Maintenance Oil and gas engineering Engineering Management

SESSION 2 (Chairs: Višnja Mihajlović, Jovana Čugalj)	
12.00-13.00h	Health and Environmental Protection
<u>35</u>	Environmental Management and Occupational Safety
13.00 - 14.00h	<i>Lunch break</i>
14.00 - 14.30h	<i>Conclusions of the conference and closing ceremony</i>

ORAL/POSTER PRESENTATION

Session 1. Mechanical Engineering		
FREE VIBRATION ANALYSYS OF A BEAM RESTING ON WINKLER ELASTIC FOUNDATION THROUGH THE SUMUDU TRANSFORM METHOD FLUID	Svetlana Lilkova-Markova, Dimitar Lolov	University of Architecture, Civil Engineering and Geodesy, Faculty of Hydraulic Engineering, Sofia, Bulgaria
DEVELOPMENT OF A MODEL FOR ASSESSING VIBRATION RISK LEVELS IN HYDROPOWER PLANT TECHNICAL SYSTEMS	Slobodan Juric, Slavica Prvulovic, Jasna Tolmac, Uros Sarenac, Ljubisa Josimovic, Milos Josimovic	High school "CEPS-Center for Business Studies" Kiseljak, Bosnia and Herzegovina
ARTIFICIAL INTELLIGENCE IN FUNCTION OF IMPROVING PRODUCT FUNCTIONALITIES	Rade Dragović, Milada Novaković, Zoran Bakić, Marija Matotek Anđelić, Igor Kostovski, Valentina Mladenović	Institute for standards and technology, Belgrade, Serbia, Technical College of Applied Sciences, Zrenjanin, Serbia, Ministry of Economy, Belgrade, Serbia, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
THE ROLE OF COOLANT IN THE ENERGY BALANCE OF INTERNAL COMBUSTION ENGINES	Juraj Marković, Hrvoje Glavaš, Mirko Karakašić, Eleonora Desnica	Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, Osijek, Croatia, University of Slavonski Brod, Mechanical Engineering Faculty, Slavonski Brod, Croatia, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
EXAMINATION OF THE SAMPLE PROPERTIES MADE BY THE ADDITIVE	Mirko Karakašić	University of Slavonski Brod, Mechanical Engineering Faculty, Slavonski Brod, Croatia
PRODUCT DEVELOPMENT OF AN INDUSTRIAL CONTROL SYSTEM FOR ROTOR WITH A FOCUS ON DESIGN FEATURES	Jure Marijić, Ivan Grgić, Marko Vilić, Mirko Karakašić, Željko Ivandić	University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod, Slavonski Brod, Croatia
THE ROLE OF CERIUM AND PRASEODIUM AS RARE-EARTH ELEMENTS IN FILLER METAL FOR BRAZING DIAMOND – AN OVERVIEW	Zoran Karastojković, Jasmina Pekez, Radiša Perić	Society for Ethics and Evaluation in the Arts and Sciences, 11000 Belgrade, Serbia, Technical Faculty, University of Novi Sad, 22000 Zrenjanin, Serbia "Perić&Perić"d.o.o., Dunavska 114-116, 12000 Požarevac, Serbia

<p>MECHANICAL CENTRIFUGATION AND PYROLISIS AS A COMBINED PROCESS FOR EFFICIENT MANAGEMENT OF OIL REFINERY SLUDGE</p>	<p>Srđan Kovačević, Nikolina Tošić, David Mitrinović, Marko Muhadinović, Galina Ilinykin, Natalia Sliusar</p>	<p>University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia Institute for the Development of Water Resources “Jaroslav Černi”, Belgrade, Serbia Lafarge BFC Srbija, d.o.o. Perm National Research Polytechnic University, Environmental Protection Department, Perm, Russia</p>
<p>THE INFLUENCE OF THE LAYER HEIGHT ON THE HARDNESS OF THE TPU PLASTIC SPECIMEN MADE BY 3D PRINTING</p>	<p>Dušan Jovanić, Eleonora Desnica, Dušan Malić</p>	<p>Technical College of Applied Sciences, Zrenjanin, Serbia University of Novi Sad, Technical Faculty “Mihajlo Pupin“, Zrenjanin, Serbia</p>
<p>EVALUATION OF THE TECHNOLOGICAL EFFECTS OF CELLULAR MANUFACTURING FOR A GROUP OF PRODUCTS</p>	<p>Dejan Lukic, Mijodrag Milosevic, Ahmet Cekic, Maida Cohodar Husic, Djerzija Begic-Hajdarevic, Dejan Bozic</p>	<p>University of Novi Sad, Faculty of Technical Sciences, DPE, Novi Sad, Serbia University of Sarajevo, Faculty of Mechanical Engineering, Sarajevo, BiH</p>
<p>THE MECHANICAL PROPERTIES OF A CIRCULAR CROSS-SECTION COLUMN MADE OF COMPOSITE MATERIAL PRODUCED USING A NEW MIXED PLASTIC RECYCLING TECHNOLOGY</p>	<p>Ljubica Lazić Vulićević, Danijela M. Jašin, Aleksandar Rajić, Valentina Mladenović, Ivan Palinkaš</p>	<p>Technical College of Applied Sciences, Zrenjanin, Serbia University of Novi Sad, Technical Faculty “Mihajlo Pupin“, Zrenjanin, Serbia</p>
<p>STRESS ANALYSIS OF CRANE SHACKLE USING FEM</p>	<p>Srđan Samardžic, Spasoje Trifković, Miroslav Milutinović</p>	<p>University of East Sarajevo, Faculty of Mechanical Engineering, Republic of Srpska, Bosnia and Herzegovina</p>
<p>BIOMIMETIC APPLICATIONS IN FLUID MECHANICS: FROM NATURE-INSPIRED DESIGNS TO TECHNOLOGICAL ADVANCEMENTS</p>	<p>Murat Ispir, Muharrem Hilmi Aksoy</p>	<p>Konya Technical University, Faculty of Engineering and Natural Science, Konya, Türkiye</p>

<p>THE DEVIATION BETWEEN INJECTED MOLDED PLASTIC PART AND FDM MANUFACTURED PART</p>	<p>Ivan Matin, Branko Štrbac, Miloš Ranisavljev, Miodrag Hadžistević, Đorđe Vukelić</p>	<p>University of Novi Sad, Faculty of Technical Sciences, Department of Production Engineering, Novi Sad, Serbia</p>
<p>ALGEBRAIC DIAMETER PROPORTION EXPRESSIONS DERIVED AND EXAMINED FOR EQUAL FLOW DISTRIBUTION BY MANIFOLD NOZZLE COUPLE</p>	<p>Eyüb Canli</p>	<p>Mechanical Engineering Department, Technology Faculty, Selcuk University, Konya, Türkiye</p>
<p>OPTIMAL LQR CONTROL OF A PENDULUM BASED OVERHEAD CRANE USING THE WHALE OPTIMIZATION ALGORITHM</p>	<p>Abdullah Çakan</p>	<p>Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Mechanical Engineering, Konya, Turkey</p>
<p>ANALYSIS OF THE SYSTEM FOR ACTIVE VIBRATION REDUCTION DURING WHEEL LOADER MOVEMENT</p>	<p>Jovan Pavlović, Dragoslav Janošević, Vesna Jovanović</p>	<p>University of Niš, Faculty of Mechanical Engineering, Niš, Serbia</p>
<p>THE DIGITAL FACTORY–PRESENT AND FUTURE</p>	<p>Stanko P. Stankov</p>	<p>University of Niš, Faculty of Electronic Engineering, Niš, Serbia</p>
<p>A SUPERVISORY CONTROL OF WATER SUPPLY SYSTEM</p>	<p>Stanko P. Stankov</p>	<p>University of Niš, Faculty of Electronic Engineering, Niš, Serbia</p>
<p>THE EXAMINATION OF OPERATIONAL CONDITION THROUGH THE VOLUMETRIC EFFICIENCY OF AN AXIAL PISTON PUMP</p>	<p>Borivoj Novaković, Luka Đorđević, Ljiljana Radovanović, Mihalj Bakator, Milan Marković, Stefan Ugrinov, Mića Đurđev</p>	<p>University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia</p>
<p>AUTOMATED DECISION SUPPORT SYSTEMS</p>	<p>Sondra Preascilla Ioana Vacarescu, Nicolae Paraschiv, Flavius-Maxim Petcuț</p>	<p>Petroleum-Gas University of Ploiesti, Romania Continental Automotive Romania Aurel Vlaicu University of Arad, Romania</p>

<p>DEVELOPMENT OF SUPPORT VECTOR MACHINE MODEL FOR CHIP FORM CLASSIFICATION IN TURNING OF POM-C</p>	<p>Miloš Madić, Milan Trifunović, Marko Kovačević</p>	<p>University of Niš, Faculty of Mechanical Engineering in Niš, Niš, Serbia Independent researcher, University of Niš, Niš, Serbia</p>
<p>DEVELOPMENT OF A MODEL FOR ASSESSING VIBRATION RISK LEVELS IN HYDROPOWER PLANT TECHNICAL SYSTEMS</p>	<p>Slobodan Juric, Slavica Prvulovic, Jasna Tolmac, Uros Sarenac, Ljubisa Josimovic, Milos Josimovic</p>	<p>University of Architecture, Civil Engineering and Geodesy, Faculty of Hydraulic Engineering, Sofia, Bulgaria</p>
<p>Session 1. Energetics and Process Technique</p>		
<p>RISK ANALYSIS USING THE INTEGRATED FTA AND FMEA MODEL ON THE EXAMPLE OF A BIOGAS PLANT</p>	<p>Jovana Radnović, Vesna Makitan</p>	<p>University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia</p>
<p>LOCALIZED STATES OF BASIC ELEMENTARY CHARGES IN ULTRATHIN CRYSTALLINE FILM-STRUCTURES</p>	<p>Nikola R. Vojnović, Dušan I. Ilić, Jovan P. Štrajčić</p>	<p>University of Novi Sad, Faculty of Technical Sciences, Trg D.Obradovića 6, 21.000 Novi Sad, Vojvodina – Serbia Academy of Sciences and Arts of the Republic of Srpska, Bana dr T.Lazarevića 1, 78.000 Banja Luka, Republic of Srpska, B&H</p>
<p>APPLICATION OF STATISTICAL METHODS IN ORDER TO DETERMINE THE LEVEL OF ENERGY EFFICIENCY</p>	<p>Čugalj Jovana, Pekez Jasmina, Stojanov Jelena</p>	<p>University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia</p>
<p>ANALYSIS OF A RESIDENTIAL PHOTOVOLTAIC SYSTEM</p>	<p>Anca-Adriana Petcuț-Lasc, Valentina-Emilia Bălaș, Flavius-Maxim Petcuț</p>	<p>Aurel Vlaicu University of Arad, Romania Petroleum-Gas University of Ploiesti, Romania</p>
<p>Session 1. Designing and Maintenance</p>		
<p>PRELIMINARY STUDY ON DRIVER POSTURE THROUGH NEW METHOD OF ANALYSIS</p>	<p>Anca SABAU, Mihaela POPA, Gabriela STOIA, Timotei Bogdan BACOȘ, Adrian Eugen CIOABLĂ</p>	<p>Faculty of Mechanical Engineering, University Politehnica Timisoara, Timisoara, Romania</p>

PROJECT MANAGEMENT AND MAINTENANCE OPTIMIZATION IN INDUSTRIAL TECHNICAL SYSTEMS	Peko Lakatuš	University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
Session 1. Oil and gas engineering		
OPTIMIZATION OF OIL PRODUCTION ON THE EXAMPLE OF LIBYA	Branislava Radišić, Snežana Komatina, Slavica Prvulović, Snežana Filip, Dragana Kovač	University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
POSSIBILITIES OF PURIFICATION OF OIL CONTAMINATED WATER USING PERLITE	Danijela Jašin, Milana Drašković, Milada Novaković	Technical College of Applied Studies, Zrenjanin, Serbia
ANALYSIS OF TEMPERATURE DROP AND HEAT LOSSES OF CRUDE OIL ALONG THE MAIN OIL PIPELINE	Jasna Tolmač, Slavica Prvulović, Saša Jovanović, Uroš Šarenac, Branislava Radišić	University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin University of Pristina, Faculty of Technical Sciences, Kosovska Mitrovica, 38220, Kosovo
Session 1. Engineering Management		
THE IMPORTANCE OF BUSINESS INCUBATORS FOR THE IMPLEMENTATION OF ENERGY MANAGEMENT	Vladimir Milošev, Rade Dragović, Igor Kostovski	University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
SUSTAINABLE SUPPLY CHAIN MANAGEMENT IN THE CONTEXT OF NATURAL RESOURCE CONSERVATION	Stefan Ugrinov, Sanja Stanisavljev, Mihalj Bakator, Edit Terek Stojanović, Mila Kavalić, Verica Gluvakov	University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
ARTIFICIAL INTELLIGENCE – AN ESSENTIAL FACTOR IN CORPORATE STRATEGIC COMMUNICATION	Zlatko Lacković, Milan Ivanović, Krešimir Lacković	Panon – think tank, Osijek, Croatia 2 Sveučilište Sjever - Koprivnica, Croatia
THE APPLICATION OF INDUSTRY 4.0 AMONG ENTREPRENEURS IN THE REPUBLIC OF SERBIA	Bojan Stankov, Sanja Stanisavljev, Mila Kavalić, Verica Gluvakov, Snežana Mirković	Hemofarm a.d. Hemofarm A.D., Beogradski put bb, 26300 Vršac, Srbija, Technical Faculty "Mihajlo Pupin", Zrenjanin, University of Novi Sad, Zrenjanin, Serbia, 5BB TRADE doo, Zrenjanin, Serbia

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GREEN BEHAVIOR OF EMPLOYEES	Dragana Kovač, Edit Terek Stojanović, Mila Kavalić, Maja Gaborov, Melita Čočkalović-Hronjec	University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia High school „Laza Kostić“, Novi Sad, Republic of Serbia
COMMISSIONING AND QUALIFICATION OF A PHARMACEUTICAL FACILITY	Ilija Tabašević, Dragan D. Milanović, Mirjana Misita	Hemofarm, Vršac, Serbia University of Belgrade, Faculty of Mechanical Engineering, Beograd, Serbia
CIRCULAR ECONOMY IN THE CONSTRUCTION SECTOR: THE SITUATION IN CROATIA	Držislav Vidaković, Marijana Hadzima-Nyarko, Laura Šoja	Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek, Osijek, Croatia Josip Juraj Strossmayer University of Osijek, Faculty of Economics and Business, Osijek, Croatia
INTRODUCING ISO 22301 INTO AN ESTABLISHED INTEGRATED MANAGEMENT SYSTEM (IMS)	Marija Perović, Marija Todorović	Jaroslav Černi Water Institute, Belgrade, Serbia
Session 2. Health and Environmental Protection		
VALIDATION OF SOME AIR POLLUTANT DISTRIBUTION MODELS	Stevo K. Jaćimovski, Dane Subošić, Jovan P. Štrajčić	University of Criminalistic and Police Studies, Zemun – Belgrade, Serbia Academy of Sciences and Arts of the Republic of Srpska, Banja Luka, B&H
EXPERIMENTAL STUDY OF FIRE HAZARDS FROM SMALL-SCALE METHANE FIRES	Milan Protić, Nikola Mišić, Ana Vukadinović, Jasmina Radosavljević, Miomir Raos	University of Niš, Faculty of Occupational Safety, Niš, Serbia
INTEGRATION OF CIRCULAR ECONOMY AND INDUSTRIAL ECOLOGY: PATHWAYS TO SUSTAINABLE INDUSTRIAL DEVELOPMENT	Vesna Drakulović, Višnja Mihajlović, Bogdana Vujić, Mića Đurđev, Milan Marković	University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia
METHODOLOGY OF DETERMINATION OF FIRE HAZARD ZONES IN THE HIGH-BAY WAREHOUSES	Goran Bošković, Višnja Mihajlović, Nikola Karanović, Natalija Nikolić, Zoran Čepić	Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, Kraljevo, Serbia Technical Faculty “Mihajlo Pupin”, University of Novi Sad, Zrenjanin, Serbia University of Aveiro, Portugal Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia

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<p align="center">GIS AND REMOTE SENSING IN FOREST FIRE ANALYSIS IN SERBIA</p>	<p align="center">Natalija Nikolić, Jovana Čugalj, Vesna Drakulović</p>	<p align="center">Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia Technical Faculty “Mihajlo Pupin” Zrenjanin, University of Novi Sad, Serbia</p>
<p align="center">PTE DISTRIBUTION FACTOR AS AN INDICATOR OF URBAN SOIL POLLUTION</p>	<p align="center">Aleksandra Mihailović, Jordana Ninkov, Selena Samardžić, Savka Adamović Robert Lakatoš, Sofija M. Forkapić, Tomas Nemeš</p>	<p align="center">University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia, Institute of Field and Vegetable Crops, National Institute of the Republic of Serbia, Maksima Gorkog 30, Novi Sad, University of Novi Sad, Serbia Faculty of Sciences, Novi Sad, Serbia</p>
<p align="center">Assessing the Potential of Photovoltaics on Austrian Railway Noise Barriers: Advancing Renewable Energy Communities and Sustainable Energy Solutions</p>	<p align="center">Milijana Keseric, Momir Tabakovic</p>	<p align="center">University of Applied Sciences Wiener Neustadt, Wieselburg, Austria University of Applied Science Technikum Wien, Vienna, Austria</p>
<p align="center">GREENWASHING: TRICK OR THREAT</p>	<p align="center">Gordana Rendulić Davidović, Milena Damnjanović, Nikola Radosavljević</p>	<p align="center">University of Kragujevac, Faculty of Technical Sciences Čačak, Serbia</p>
<p align="center">PREDICTION OF LANDFILL FIRE AND ENVIRONMENTAL IMPACT HAZARD ZONES: CASE STUDY OF THE SANITARY LANDFILL IN PIROT</p>	<p align="center">Lidija Milošević, Emina Mihajlović, Amelija Đorđević, Jelena Malenović</p>	<p align="center">University of Niš, Faculty of Occupational safety in Niš, Niš</p>
<p align="center">DISTRIBUTION OF PCB CONGENERS IN ENVIRONMENTAL MEDIA</p>	<p align="center">Nada Markovic, Nebojsa Ralevic</p>	<p align="center">Directorate for Inspection Affairs, Podgorica, Montenegro University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia</p>

<p>ASSESMENT OF WATERBORNE TRANSPORT SECTOR IMPACT ON EUROPE AIR QUALITY WITH SHERPA MODEL</p>	<p>Madalina Zot, Francisc Popescu</p>	<p>University Politehnica Timisoara, Timisoara, Romania</p>
<p>NAVIGATING TOWARDS ZERO-EMISSION DISTRICT HEATING: THE DANISH GOOD PRACTICE EXAMPLE FROM ESBJERG</p>	<p>Borivoj Lj. Stepanov, Zoran M. Čepić, Đorđije D. Doder</p>	<p>University of Novi Sad, Faculty of Technical Sciences, Department of Energy and Process Engineering, Novi Sad, Serbia University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Safety at work, Novi Sad, Serbia</p>
<p>IMPACT OF FUEL CONSUMPTION ON CO2 EMISSIONS IN ROAD TRANSPORT IN EUROPEAN COUNTRIES</p>	<p>Ermina Ćosović, Ivan Mihajlović, Vesna Spasojević Brkić</p>	<p>University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia</p>
<p>EVALUATING MICROPOLLUTANTS IN THE DANUBE RIVER: ASSESSING CONCENTRATIONS AND ENVIRONMENTAL IMPACT</p>	<p>Marija Perović</p>	<p>Jaroslav Černi Water Institute, Belgrade, Serbia</p>
<p>APPLICATION OF THE MACHINE LEARNING IN SURFACE WATER QUALITY ASSESSMENT</p>	<p>Jelena Antović, Katarina Batalović, Ivana Mihajlović</p>	<p>University of Priština, Faculty of Technical Sciences, Knjaza Milosa 7, Kosovska Mitrovica 38220 VINČA Institute of Nuclear Sciences—National Institute of the Republic of Serbia, University of Belgrade, Mike Petrovica Alasa 12–14, Belgrade 11000, Serbia University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovića 6, Novi Sad 21000, Serbia</p>

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<p align="center">COMPARATIVE STUDY OF SODA LAKES AND PANS CHEMICAL PROPERTIES IN SERBIA AND HUNGARY</p>	<p align="center">Nevena Živančev, Srđan Kovačević, Ivana Mihajlović</p>	<p align="center">University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia</p>
<p align="center">THE NECESSITY OF ROOFTOP GREENHOUSES FOR IMPROVING URBAN AIR QUALITY AND TEMPERATURE REGULATION</p>	<p align="center">Mihaela POPA, Valentina-Emilia BĂLAȘ</p>	<p align="center">Petroleum-Gas University of Ploiesti, Romania Aurel Vlaicu University of Arad, Romania Academy of Romanian Scientists</p>
<p align="center">AQUAPONICS AS AN INNOVATIVE TECHNOLOGY FOR SUSTAINABILITY AND ENVIRONMENTAL PROTECTION: CHALLENGES AND INDUSTRIAL SOLUTIONS</p>	<p align="center">Daniel Alexuță, Marius M. Bălaș</p>	<p align="center">Aurel Vlaicu University of Arad, Romania Petroleum-Gas University of Ploiesti, Romania</p>
<p align="center">ASSESSING THE LANDSCAPE OF HAZARDOUS CHEMICALS MANAGEMENT</p>	<p align="center">Dunja Istrat, Jelena Ćulibrk, Maja Petrović</p>	<p align="center">University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia</p>
<p align="center">NEOLIBERALISM AND CLIMATE CHANGE: TOWARDS A SUSTAINABLE ECONOMY THROUGH THE GREEN NEW DEAL</p>	<p align="center">Edi Daruși</p>	<p align="center">Tehnički fakultet “Mihajlo Pupin”, Zrenjanin, Serbia</p>
<p align="center">EXTENDING THE APPLICATION OF VR/AR TECHNOLOGY TO IMPROVE SAFETY TRAINING IN THE CRUDE OIL INDUSTRY</p>	<p align="center">Adrijana Babić, Zoran Čepić</p>	<p align="center">University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg D. Obradovića 6, Novi Sad, Serbia</p>

<p>NEITHER ANTHROPOCENE NOR CAPITALOCENE - A PATH TOWARD AN ANTI-CAPITALIST ECOLOGY</p>	<p>Dejan Mihailović, Alexis Toribio Dantas</p>	<p>Tecnológico de Monterrey, Ciudad México, México Rio de Janeiro State University, Rio de Janeiro, Brasil</p>
<p>AQUAPONICS AS AN INNOVATIVE TECHNOLOGY FOR SUSTAINABILITY AND ENVIRONMENTAL PROTECTION: CHALLENGES AND INDUSTRIAL SOLUTIONS</p>	<p>Daniel Alexuță, Marius M. Bălaș</p>	<p>Aurel Vlaicu University of Arad, Romania Petroleum-Gas University of Ploiesti, Romania</p>
<p>Session 2. Environmental Management and Occupational Safety</p>		
<p>EU GREEN TRANSITION DOES NOT HAVE A PLANETARY APPROACH</p>	<p>Milan Ivanović</p>	<p>Panon, think tank for strategic studies, Osijek, Croatia</p>
<p>PSYCHOSOCIAL RISKS AND STRESS IN THE WORKPLACE</p>	<p>Dijana Vašaš Kuručev, Milica Bogdanov, Jasmina Poštin, Sanja Stankov, Milan Nikolić</p>	<p>University "Union – Nikola Tesla", Beograd, "Faculty of Management", Sremski Karlovci, Serbia University of Belgrade, Faculty of Philosophy, Belgrade, Serbia University of Novi Sad, Technical Faculty "Mihajlo Pupin," Zrenjanin, Serbia</p>
<p>THE IMPACT OF TRAINING AND EDUCATION ON REDUCING WORKPLACE INJURIES</p>	<p>Milica Bogdanov, Dijana Vašaš Kuručev, Jasmina Poštin, Sanja Stankov, Milan Nikolić</p>	<p>University of Belgrade, Faculty of Philosophy, Belgrade, Serbia University "Union – Nikola Tesla", Beograd, "Faculty of Management", Sremski Karlovci, Serbia University of Novi Sad, Technical Faculty "Mihajlo Pupin," Zrenjanin, Serbia</p>

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GREEN TECHNOLOGIES AND THEIR ROLE IN URBAN SUSTAINABILITY INITIATIVES	Mihalj Bakator, Luka Đorđević, Borivoj Novaković, Velibor Premčevski, Stefan Ugrinov	University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
SUSTAINABILITY AS A CORE COMPONENT OF QUALITY STANDARDS IN MODERN BUSINESSES	Dragan Čočkalo, Mihalj Bakator, Milan Nikolić, Sanja Stanisavljev, Verica Gluvakov	University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
ANALYSIS OF RISK ASSESSMENT CONDUCTED IN THE GARMENT INDUSTRY IN NORTH MACEDONIA	Monika Lutovska, Vladimir Mijakovski	Institution Faculty of Technical Sciences, "Mother Teresa" University, Skopje, MK Faculty of Technical Sciences, University „St. Kliment Ohridski”, Bitola, MK)
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IIZS 2024

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We are pleased to inform you that your paper has been accepted by the Scientific Committee and will be published in the Proceedings of the XIV International Conference on Industrial Engineering and Environmental Protection (IIZS 2024). The Conference event will be held on **October 3-4, 2024**, at the **Technical Faculty "Mihajlo Pupin" Zrenjanin, Serbia**.

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Author(s)	Marija Perović

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INTRODUCTION

Department of mechanical engineering and Department of environmental protection of Technical Faculty "Mihajlo Pupin", Zrenjanin, has organized the XIV International Conference Industrial Engineering and Environmental Protection – IIZS 2024.

The topics of scientific conference «IIZS 2024», cover the fields of Industrial Engineering and Environmental protection: Mechanical Engineering, Energetics and process technique, Designing and maintenance, Oil and gas engineering, Health and environmental protection, Environmental management, Occupational safety and Engineering management.

The main goals of the conference are: fostering innovation and expanding knowledge for engineers in industry and environmental protection; supporting researchers in presenting their current research results; establishing new contacts with premier national and international institutions and universities; popularizing the Faculty and its leadership role in our society and immediate environment, to attract a high-quality young individuals to study at our Faculty; cooperating with other organizations, public companies, and industry; initiating the collection of ideas for solving specific practical problems; interconnecting and establishing business contacts; introducing professional and business organizations to the results of scientific and technical research; and presenting scientific knowledge and exchanging experiences in industrial engineering.

We would like to express our gratitude to the partners of the IX International Conference "IIZS 2024" – Aurel Vlaicu University of Arad, Faculty of Engineering, Arad, Romania; University St. Kliment Ohridski, Technical Faculty, Bitola, Macedonia; University Politehnica Timisoara, Faculty of Engineering, Hunedoara, Romania; University of East Sarajevo, Faculty of Mechanical Engineering, East Sarajevo, B&H, Republic of Srpska; and University of Giresun, Faculty of Engineering, Giresun, Turkey – for their support in organizing this event. We are also grateful to all the authors who have contributed their papers to the scientific meeting "IIZS 2024".

We would like to extend our special thanks to the Ministry of Education, Science and Technological Development, Republic of Serbia, and the management of Technical Faculty "Mihajlo Pupin", University of Novi Sad, for supporting the organization of the Conference "IIZS 2024".

The IIZS Conference has become a traditional annual meeting for researchers from around the world. We are open to and grateful for any useful suggestions that could help make the next, XV International Conference on Industrial Engineering and Environmental Protection even better, both organizationally and programmatically.

Chairman of the Organizing Committee
Asst. Prof. Jasna Tolmač, PhD

Zrenjanin, October 3-4, 2024.

Conference participants are from the following countries:



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EVALUATING MICROPOLLUTANTS IN THE DANUBE RIVER: ASSESSING CONCENTRATIONS AND ENVIRONMENTAL IMPACT

Keynote paper

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Abstract: Freshwater pollution poses a significant global challenge, largely driven by the continuous release of synthetic organic substances into the environment. This persistent contamination underscores the urgent need for a thorough understanding of the chemical status of Earth's surface waters. Even trace amounts (ng/L; µg/L) of these substances, known as micropollutants, can accumulate in aquatic ecosystems, posing risks to both biodiversity and human health. This research examines key water quality parameters of the Danube River in Serbia, focusing on the prevalence of micropollutants within a river basin that spans 92% of the country's land area and 10% of the entire Danube basin. It also provides an overview of existing regulatory frameworks that set limit values for these contaminants. By reviewing official data on hazardous substances and other pollutants concentration, the study provides valuable insights into water quality challenges and offers guidance for future management strategies aimed at addressing micropollutants.

Key words: Danube, micropollutants, hazardous substances

INTRODUCTION

The entire life cycle of a product from production and processing to use and disposal can lead to the release of hazardous substances. These include household and industrial chemicals, pollutants from transportation (such as hydrocarbons and heavy metals), as well as pesticides widely used in agriculture and along roads and railways [1]. Micropollutants (MPs) are found in trace amounts across various environmental compartments and organisms. They include a wide range of contaminants, some of which are classified as priority substances (PSs) under environmental regulations due to their persistence, toxicity, and potential to bioaccumulate, posing significant risks to human health and the environment. Key groups of MPs include pharmaceuticals, personal care products, pesticides, trace metals, persistent organic pollutants, micro- and nanoplastics, artificial sweeteners, and other compounds that pose potential threats to ecological systems [2]. Urban wastewater treatment plants are significant point sources of hazardous substances, as conventional treatment methods, such as coagulation, sedimentation, sand filtration, chlorination, biological degradation, and UV irradiation, often fail to remove MPs, including Per- and Polyfluoroalkyl Substances (PFAS) [3,4]. Agricultural activities are a major source of MPs, primarily due to the extensive use of pesticides, which contaminate surface waters through runoff, leaching, and erosion, and reach groundwater through permeable soils and water percolation. The most studied PSs worldwide, are pesticides, including atrazine, simazine, chlorpyrifos, terbutryn, diuron, and alachlor [5]. Although soil can absorb and retain metals, emissions from agriculture, such as cadmium from phosphate fertilizers, zinc from animal feed, and copper used in feed, treatments, and disinfection, remain significant environmental concerns. PFAS comprise a broad range of over 4,700 synthetic compounds, attracting increasing attention due to their ubiquity in both the environment and human populations worldwide. Perfluorooctanoic acid (PFOA) and Perfluorooctane sulfonate (PFOS), are among the most widely used, frequently detected, and extensively studied PFAS in the environment [6]. They are used in cosmetics, textiles for stain and water repellence, adhesives, fire-fighting foams, paper products. Additionally, PFAS are found in semiconductors, lubricants, coating additives, cookware and food packaging, surfactants, agricultural applications, pesticides, and as erosion inhibitors in aviation [7-9]. Their presence in surface and groundwater highlights the connection between human activity and the hydrological cycle [10]. Although many hazardous substances have been banned or phased out, surface and groundwater contamination persist due to their past use and ongoing

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illegal applications. This is evidenced by the continued detection of notable concentrations of these substances and their metabolites in the environment [11,12].

Legislative Framework for Pollutants and Hazardous Substances in water

Since its inception in 2000, the Water Framework Directive (WFD) has been the cornerstone of water protection in Europe, alongside the Environmental Quality Standards Directive (EQSD) and the Groundwater Directive. The WFD aims to protect inland surface waters, transitional waters, coastal waters, and groundwater by reducing discharges and emissions of priority substances (PS) and phasing out or minimizing those of priority hazardous substances (PHSs) through targeted regulations and benchmarks. The WFD identifies surface water pollutants of significant EU-wide concern as PS, including PHS listed in Annex X, with environmental standards set by the EQSD. Article 2 of the WFD defines hazardous substances as those that are toxic, persistent, and prone to bioaccumulation, or that raise similar concerns. Article 4 outlines the environmental objectives, requiring Member States to implement measures to reduce pollution from PS and to phase out emissions, discharges, and losses of PHS. The WFD requires EU Member States to closely monitor potential pollutants through a Watch List (WL) for surface waters [13]. The monitoring of PSs and contaminants of emerging concern is governed by Directive 2013/39/EU and the updated WL under Decision (EU) 2022/1307/EU. The WFD requires that for international river basins extending beyond EU borders, a single river basin management plan should be developed. Under the WFD, pollution from hazardous substances is a critical water quality issue that must be addressed in the Danube River Basin (DRB). This obligation also extends to non-EU Member States, which have committed to achieving similar objectives under the framework of the International Commission for the Protection of the Danube River (ICPDR). In 2000, ICPDR countries, including non-EU states, agreed to implement this directive across the entire Danube basin. The Federal Republic of Yugoslavia ratified the Convention on the Protection and Sustainable Use of the Danube River in 2003 and enacted the corresponding law. In the same year, Serbia, as part of the State Union of Serbia and Montenegro, joined the ICPDR.

In the Republic of Serbia within the Water Law ("Official Gazette of the Republic of Serbia", No. 30/2010, 93/2012, 101/2016, 95/2018, and 95/2018 - amended law) the Priority substances are those identified as posing significant risks to the aquatic environment or to other areas through it, as determined by specific regulations. This category includes "priority hazardous substances," which are selected priority substances that present an increased risk to human health or the environment. In Serbia the list of priority and priority hazardous substances and its Average annual concentrations (AAC) and Maximum allowable concentrations (MAC) are defined in Regulation on limit values of priority and priority hazardous substances that pollute the surface waters and deadlines for their achievement ("Official Gazette of the Republic of Serbia", No. 24/2014). This list is in accordance with Annex X of the WFD. In addition to the aforementioned, the Regulation on Limit Values of Pollutants in Surface and Groundwater and Sediment, and Deadlines for Their Achievement ("Official Gazette of the RS", No. 50/2012) defines the limit values of pollutants in surface and groundwater, as well as in sediment, along with the deadlines for achieving these values.

Around 90% of Serbia's renewable water resources come from outside its borders, emphasizing the crucial need for international cooperation [14]. Serbia, spanning 88,499 km², is predominantly within the Danube Basin, which covers 92% of its land and 10% of the total basin area [14]. Municipal sources are the primary contributors to pollution in Serbia, while emissions from industry are considered the primary source of hazardous substances in Serbia [14,15]. Agricultural pollution mainly stems from livestock farming, with minor contributions from mineral fertilizers used on non-irrigated lands [14].

This research aims to assess the presence and concentration of micropollutants, in the Serbian section of the Danube River using official data from the National Surface Water Quality Monitoring Program of the Serbian Environmental Protection Agency (SEPA). The scope includes identifying which priority substances and pollutants are detectable in the Danube section in Serbia.

MATERIAL AND METHODS

In this study, selected water quality data for the Danube River along its course through Serbia were analyzed, sourced from the National Surface Water Quality Monitoring Program of the Serbian Environmental Protection Agency (SEPA). From the SEPA's results of the examination of physical-chemical, chemical, and microbiological parameters for assessing the status of surface water the selected physical-chemical and chemical parameters of surface water, priority and priority hazardous substances and other pollutants were analyzed. Basic descriptive statistics for selected water quality parameters over a seven-year period (2016–2022), with monthly sampling frequency, was done. A total of 576 samples collected from Bezdán, Bogojevo, Novi Sad, Zemun, Smederevo, Banatska Palanka, and Tekija were all analyzed (Fig. 1).

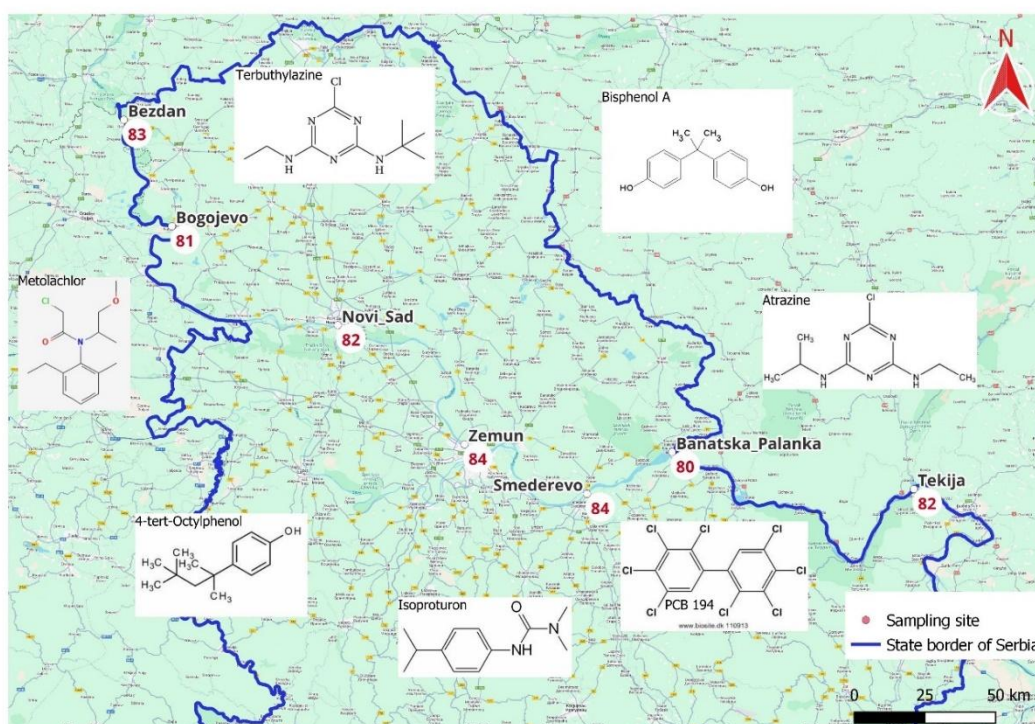


Fig. 1. Sampling Locations with Marked Number of Samples

RESULTS AND DISCUSSION

Table 1 presents the basic descriptive statistics for key water quality parameters specific to the Serbian section of the Danube River, providing an overall summary for all sampling locations combined. The range of electrical conductivity of water is from 291.0 $\mu\text{S}/\text{cm}$ to 600.0 $\mu\text{S}/\text{cm}$, while median values (50th percentile) for NH_4^+ , NO_3^- and Cl are 0.08 mgN/l, 1.01 mgN/l and 19.95 mg/l respectively. The range of quantified boron is moderate, from below limit of quantification <10 $\mu\text{g}/\text{l}$ to 253.5 $\mu\text{g}/\text{l}$. Seventy-five percent of the analyzed samples exhibit a chemical oxygen demand of up to 4.40 mg/l, indicating a moderate organic load in analysed water.

Although the measured range of total organic carbon (TOC) is quite broad, 75% of the samples show quantified concentrations of up to 4.80 mg/l. Additionally, the Biochemical Oxygen Demand (BPK5), which reflects the oxygen consumption by bacteria during the decomposition of organic matter in the water, averages 2.12 mg/l, with values ranging from a minimum of 0.60 mg/l to a maximum of 5.60 mg/l. This indicates that organic pollution is present but remains at manageable levels.

Table 2 provides basic descriptive statistics for selected metals, including cadmium (Cd), lead (Pb), nickel (Ni), zinc (Zn), copper (Cu), chromium (Cr), and metalloid arsenic (As). The largest concentration ranges are observed for Cu, Zn, and Ni. Total Cd was found at a mean concentration of 0.05 µg/l, with values ranging from less than 0.02 µg/l to 1.00 µg/l, indicating minimal contamination in most samples. Total Ni exhibited a mean concentration of 7.52 µg/l, with a notable range from less than 0.5 µg/l to 412.20 µg/l, suggesting sporadic pollution sources. Total Pb had a mean concentration of 1.39 µg/l, ranging from less than 0.5 µg/l to 30.10 µg/l, indicating generally low levels but highlighting potential localized pollution. Total Cr concentrations ranged from less than 0.5 µg/l to 58.00 µg/l, suggesting predominantly low levels; Zn and Cu exhibited significant concentration ranges, from less than 10 µg/l to 671.70 µg/l and from less than 1 µg/l to 834.30 µg/l, respectively, indicating influences from anthropogenic sources. As (total) was found with a mean concentration of 5.99 µg/l, ranging from 0.50 µg/l to 361.10 µg/l. The higher concentrations of arsenic raise health concerns and underscore the need for more detailed ongoing surveillance. While most metals are present at low concentrations, the significant variability, particularly in nickel, zinc, copper, and arsenic levels, emphasizes the necessity for continuous monitoring and more detailed data assessments to identify potential pollution sources and protect water quality.

Table 3 lists priority and priority hazardous substances detected above the limit of quantification (LOQ) in over 30% of samples, along with their applicable limit values as defined in the Regulation on Limit Values of Priority and Priority Hazardous Substances Polluting Surface Waters and Deadlines for Their Achievement ('Official Gazette of RS,' No. 24/2014). It should be noted that not all substances have prescribed limit values. Among these, the compounds identified include industrial chemicals such as organic derivatives of phenol (para-tert-octylphenol), PCB 194, and bisphenol A and pesticides (atrazine, terbuthylazine, metolachlor, and isoproturon) (Table 3). The same Regulation prescribes an AAC of 6.5×10^{-4} µg/L and a MAC of 36 µg/L for PFOS and its derivatives, but these compounds are not part of the regular monitoring in Serbia. Table 4 presents priority substances, metals cadmium (Cd), lead (Pb), and nickel (Ni) along with their limit values as regulated by the Regulation on Limit Values of Priority and Hazardous Substances Polluting Surface Waters and Deadlines for Their Achievement ("Official Gazette of RS," No. 24/2014). Table 5 outlines the prescribed limit values for polluting substances in surface waters, specifically chromium (Cr), copper (Cu), zinc (Zn), and metalloid arsenic (As). These limit values are established by the Regulation on limit values of pollutants in surface and groundwater and sediment and on deadlines for their achievement ("Official Gazette of the RS," No. 50/2012). Priority substances quantified in more than 30% of the measurements above the LOQ, which are part of both operational and surveillance monitoring (excluding metals), were selected for presentation and further discussion.

Organic derivatives of phenol, like Para-tert-Octylphenol (OP), are hazardous endocrine-disrupting compounds with significant environmental and health impacts. Primarily used in phenolic resin and lacquer production, OP exhibits weak estrogen-like activity and has been found in various environmental compartments, including water, phytoplankton, zooplankton, mussels, and fish tissues. Its concentration, influenced by diet and habitat, suggests bioaccumulation potential [16]. OP disrupts hormone regulation, affecting reproduction, growth, and behavior, and can mimic the sex hormone 17β-estradiol, leading to feminization in aquatic life and developmental issues in humans, including cancers of the sex organs [16]. The presence of alkylphenolic compounds along the Danube River highlights widespread wastewater contamination with varying impacts [17].

PCB 194, a synthetic organic compound classified as 2,2',3,3',4,4',5,5'-octachlorobiphenyl, belongs to the polychlorinated biphenyl (PCB) group. Despite being banned decades ago, PCBs persist in the environment due to their bioaccumulative properties and ongoing releases from historical industrial activities, spills, and thermal processes [18]. They can exist in vapor or particulate form and disrupt hormonal, reproductive, immune, and endocrine functions, leading to severe health issues, including cancer, birth defects, and cognitive impairments. Bisphenol A (BPA; 4,4'-dihydroxy-2,2-diphenylpropane) is a widely used chemical in the production of polycarbonate plastics, epoxy resins, and as a non-polymer additive in PVC. It

can be found in products like shatterproof windows, eyewear, water bottles, and epoxy-coated metal food cans. While BPA is rapidly metabolized and excreted in urine, biomonitoring studies have detected unconjugated BPA, indicating ongoing internal exposure risks [19]. Human exposure primarily occurs through the consumption of food and bottled mineral water.

Atrazine, a chlorinated herbicide from the triazine class, is mainly used to control broadleaf weeds in crops like maize, soybean, and sugarcane, as well as in turf areas. As an endocrine disruptor, it can cause reproductive issues, behavioral changes, and impaired fetal growth, and is linked to birth defects and various cancers, including non-Hodgkin lymphoma and breast cancer [20]. In aquatic environments, atrazine degrades into metabolites such as deethylatrazine (DEA), deisopropylatrazine (DIA), and deethyl-deisopropylatrazine (DEIA). Given atrazine's half-life in water of 105 to over 200 days, its detection in the Danube suggests ongoing use, despite the ban on atrazine-containing herbicides in Serbia since 2007. This ban was implemented by the Plant Protection Administration of the Ministry of Agriculture, Forestry, and Water Management [21].

Terbuthylazine (TBA) has largely replaced atrazine in several EU countries and is now a widely used pesticide and one of the most frequently detected in continental and coastal waters with its metabolite desethylterbuthylazine (DET) being prevalent in EU aquifers [22]. DET is more water-soluble and binds less to organic matter, increasing the risk of groundwater contamination. Both TBA and DET are emerging chemicals of concern due to their persistence and toxicity to aquatic life, as well as their significant endocrine-disrupting effects on wildlife and humans. Metolachlor, a selective herbicide for annual grass weeds and certain broadleaf species, raises concerns due to evidence of bioaccumulation in edible fish and negative impacts on growth and development. Isoproturon, another selective herbicide, is used for controlling broadleaf weeds and grasses in crops. It has low acute toxicity, but related chemicals like monolinuron and linuron can cause developmental malformations. Data on environmental levels of isoproturon are limited, but exposure to the general population appears minimal, with health effects mainly studied in occupational settings.

The selected parameters represent micropollutants, detected above the limit of quantification in more than 30% of cases, providing insights into which substances are present in the Danube River. It is important to emphasize that these substances have not been analyzed in terms of whether the quantified average annual concentration or maximum concentrations exceed the prescribed limit values, as the presented data processing (overall summary for all sampling locations combined) does not correspond to that type of interpretation. The study aimed to identify which substances are present above the quantification limit, indicating their actual occurrence.

Table 1. Basic Descriptive Statistics of selected parameters for the section of the Danube River flowing through Serbia (based on SEPA data, 2016–2022)

	Flow	Susp.*	pH	Ec**	NH ₄	NO ₃	Cl	B	COD KMnO ₄	BPK ₅	TOC	
Unit	m ³ /s	mg/l	/	µS/cm	mgN/l	mgN/l	mg/l	µg/l	mg/l	mg/l	mg/l	
No of samples	342	570	568	576	576	576	576	372	575	571	500	
Mean	2932	20.4	8.09	402.9	0.10	1.16	20.60	31.00	3.90	2.12	4.11	
Std. dev.	1371	20.3	0.21	54.4	0.07	0.55	5.16	23.17	1.07	0.75	1.14	
Min.	1020	<4	7.08	291.0	<0.02	0.14	5.40	<10	1.29	0.60	1.30	
Max.	9610	178.0	8.80	600.0	0.35	3.24	41.98	253.50	12.06	5.60	11.00	
Percentile	25	1975	7.0	7.96	359.0	0.04	0.80	16.80	19.43	3.20	1.60	3.40
	50	2700	15.0	8.09	393.5	0.08	1.01	19.95	26.40	3.70	2.10	4.00
	75	3420	27.0	8.20	442.0	0.14	1.40	23.38	37.08	4.40	2.50	4.80

Susp.* - suspended solids

Ec** - electrical conductivity

Table 2 Basic Descriptive Statistics of selected metals (and metalloid As) for the section of the Danube River flowing through Serbia (based on SEPA data, 2016–2022)

	Cd	Cd diss	Ni	Ni diss	Pb	Pb diss	Cr	Cr diss	Zn	Zn diss	Cu	Cu diss	As	As diss	
Unit	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	
No of samples	399	438	399	438	399	440	398	436	398	407	399	437	398	433	
Mean	0.05	0.03	7.52	3.63	1.39	0.43	1.76	0.74	52.69	30.97	15.22	7.63	5.99	3.02	
St.dev.	0.08	0.09	23.23	5.87	1.86	0.65	3.93	1.95	79.27	54.10	46.43	14.78	32.27	17.44	
Min.	<0.02	<0.02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	<10	<1	<1	0.50	<0.5	
Max.	1.00	1.76	412.20	74.40	30.10	9.30	58.00	36.80	671.70	423.00	834.30	148.60	361.10	287.80	
Percentile	25	<0.02	<0.02	1.90	1.20	0.60	<0.5	0.70	<0.5	15.40	<10	4.70	2.30	1.50	1.20
	50	0.03	0.02	2.90	1.90	1.10	<0.5	1.00	<0.5	26.10	14.00	6.80	3.80	1.80	1.50
	75	0.06	0.03	6.45	3.60	1.60	<0.5	1.58	0.70	51.15	26.25	12.35	6.70	2.00	

Diss – dissolved

Table 3 Statistical metrics for analysing priority and priority hazardous substances and other pollutants quantified above quantification limit (LOQ) in more than 30% of samples in Danube River in Serbia (based on SEPA data, 2016–2022)

Parameter	Unit	No of samples	No of measurements above LOQ	Percentage of Measurements Above LOQ of Total Measurements	Maximum quantified concentration	Priority Hazardous Substances (PHS)*	Prescribed AAC (µg/l) *	Prescribed MAC (µg/l) *
Para-tert-Octylphenol	µg/l	434	139	32	0.162	No	0.1	/
Atrazine	µg/l	434	220	51	0.161	No	0.6	2
Desethylterbutylazine	µg/l	434	252	58	0.045	Not Covered by Regulation*	Not Covered by Regulation*	Not Covered by Regulation*
Terbutylazine	µg/l	434	360	83	1.672	Not Covered by Regulation*	Not Covered by Regulation*	Not Covered by Regulation*
Metolachlor	µg/l	432	354	82	0.71	Not Covered by Regulation*	Not Covered by Regulation*	Not Covered by Regulation*
Isoproturon	µg/l	434	223	51	0.02	No	0.3	1
PCB-194	µg/l	98	89	91	117.6	Not Covered by Regulation*	Not Covered by Regulation*	Not Covered by Regulation*
Bisphenol A	µg/l	297	117	39	0.165	Not Covered by Regulation*	Not Covered by Regulation*	Not Covered by Regulation*

* Regulation on limit values of priority and priority hazardous substances that pollute the surface waters and deadlines for their achievement ("Official Gazette of RS," No. 24/2014)

Table 4 Prescribed limit values According to Regulation on limit values of priority and priority hazardous substances that pollute the surface waters and deadlines for their achievement "Official Gazette of RS," No. 24/2014 ("Official Gazette of RS," No. 24/2014)

Parameter	Unit	Priority Hazardous Substances (PHS)	Prescribed Average Annual Concentration (AAC) (µg/l)	Prescribed Maximum Allowable Concentration (MAC) (µg/l)
Cd and its compounds (depending on water hardness* class)	µg/l	Yes	<0,08 (class 1) 0,08 (class 2) 0,09 (class 3) 0,15 (class 4) 0,25 (class 5)	<0,45 (class 1) 0,45 (class 2) 0,6 (class 3) 0,9 (class 4) 1,5 (class 5)
Pb and its compounds**	µg/l	No	1.2	14
Ni and its compounds	µg/l	No	4	34

*For cadmium and its compounds, the limit value varies depending on the hardness of water, which is categorized into five classes (Class 1: <40 mg CaCO₃/L, Class 2: 40 to <50 mg CaCO₃/L, Class 3: 50 to <100 mg CaCO₃/L, Class 4: 100 to <200 mg CaCO₃/L, and Class 5: ≥200 mg CaCO₃/L)

** These values for the environmental quality standard indicate the concentrations of substances that are bioavailable.

Table 5 Prescribed limit values of polluting substances in surface waters according to Regulation on limit values of pollutants in surface and groundwater and sediment and on deadlines for their achievement ("Official Gazette of the RS," No. 50/2012)

Parameter	Unit	Limit Values ⁽¹⁾				
		Class I ⁽²⁾	Class II ⁽³⁾	Class III ⁽⁴⁾	Class IV ⁽⁵⁾	Class V ⁽⁶⁾
Cr (total)	µg/l	25 (or NL)	50	100	250	>250
Cu	µg/l	5 (T=10) 22 (T=50) 40 (T=100) 112 (T=300)	5 (T=10) 22 (T=50) 40 (T=100) 112 (T=300)	500	1000	>1000
Zn	µg/l	30 (T=10) 200 (T=50) 300 (T=100) 500 (T=500)	300 (T=10) 700 (T=50) 1000 (T=100) 2000 (T=500)	2000	5000	>5000
As	µg/l	<5 or NL	10	50	100	>100

(1) Unless otherwise specified, the values are expressed as total concentrations in the sampled specimen

(2) The description of this class corresponds to an excellent ecological status according to the classification provided in the regulation that stipulates the parameters for ecological and chemical status for surface waters. Surface waters belonging to this class ensure, based on the limit values of quality elements, conditions for the functioning of ecosystems, the life and protection of fish (salmonids and cyprinids), and can be used for the following purposes: drinking water supply with prior treatment through filtration and disinfection, bathing and recreation, irrigation, and industrial use (process and cooling water).

(3) The description of this class corresponds to a good ecological status according to the classification provided in the regulation that stipulates the parameters for ecological and chemical status for surface waters. Surface waters belonging to this class ensure, based on the limit values of quality elements, conditions for the functioning of ecosystems, the life and protection of fish (cyprinids), and can be used for the same purposes and under the same conditions as surface waters belonging to Class I.

(4) The description of this class corresponds to a moderate ecological status according to the classification provided in the regulation that stipulates the parameters for ecological and chemical status for surface waters. Surface waters belonging to this class ensure, based on the limit values of quality elements, conditions for the life and protection of cyprinids and can be used for the following purposes: drinking water supply with prior treatment through coagulation, flocculation, filtration, and disinfection, bathing and recreation, irrigation, and industrial use (process and cooling water).

(5) The description of this class corresponds to a poor ecological status according to the classification provided in the regulation that stipulates the parameters for ecological and chemical status for surface waters. Surface waters belonging to this class can be used for the following purposes based on the limit values of quality elements: drinking water supply with the application of a combination of previously mentioned treatments and enhanced treatment methods, irrigation, and industrial use (process and cooling water).

(6) The description of this class corresponds to a bad ecological status according to the classification provided in the regulation that stipulates the parameters for ecological and chemical status for surface waters. Surface waters belonging to this class cannot be used for any purpose.

T - water hardness (mg/L CaCO₃)

NL – natural level (According to the Regulation on the limit values of polluting substances in surface and groundwater and sediment and deadlines for their achievement ("Official Gazette of the Republic of Serbia," No. 50/2012), is the concentration of a polluting substance that corresponds to a state of groundwater bodies whose undisturbed conditions are not subject to changes resulting from anthropogenic effects, or where such changes are very minor).

CONCLUSION

Potential pollution sources for aquatic environments include industrial activities, mines, tailings, waste disposal sites, landfills, wastewater and agricultural pesticide use. Despite the recognized significance of these pollutants in water management issues within Serbia, systematic data collection regarding these sources and their contributions to water quality is lacking [15]. Thus, it is crucial to intensify research efforts and improve monitoring practices to accurately assess the pressures exerted by these sources on water bodies. This study analyzed the quality of 576 water samples collected from various locations along the Danube River in Serbia, including Bezdán, Bogojevo, Novi Sad, Zemun, Smederevo, Banatska Palanka, and Tekija, in the period 2016-2022 (overall summary for all sampling locations combined). While metals such as Cd, Pb, Ni, Zn, Cu, Cr, and metalloid As are part of Serbia's official monitoring, the emphasis was placed on the frequency of detection of additional pollutants and hazardous substances. Results revealed that industrial chemicals, including para-tert-octylphenol, PCB 194, and bisphenol A, along with pesticides such as atrazine, terbuthylazine, metolachlor, and isoproturon, were detected above the limit of quantification in over 30% of the samples analyzed. Currently, there is insufficient data on pesticide usage and a lack of a comprehensive database detailing the quantities of chemicals applied in agriculture [15]. To better understand trends in pollutant concentrations and potential sources, a detailed analysis based on sampling locations is necessary, along with a spatial comparison of pollutant distributions across Serbia. The investigation of correlations between seasonal water level fluctuations and pollution concentration parameters is recommended to further elucidate the dynamics of these pollutants and their sources in the Danube River Basin.

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XIV International Conference on
**INDUSTRIAL ENGINEERING AND
ENVIRONMENTAL PROTECTION**
IIZS 2024

On behalf of the Organizing Committee, I would like to invite you to participate in the International Conference on "INDUSTRIAL ENGINEERING AND ENVIRONMENTAL PROTECTION" - IIZS 2024. We are delighted to invite you to deliver an invited lecture during the event.

The Conference is an annual event organized jointly by departments of the Technical Faculty "Mihajlo Pupin" Zrenjanin and International partners.

The Conference will be held on October 4, 2024, at the Technical Faculty "Mihajlo Pupin" in Zrenjanin, Serbia. The opening ceremony is at 10 a.m. in the meeting room on the 2nd floor.

Any further information regarding the event can be found on our website:
<http://www.tfzr.uns.ac.rs/iizs/index.php>

We remain at your service for any further assistance you may need, and we look forward to welcoming you to Zrenjanin.

Welcome to IZZS 2024!

Warm Regards,

Asst. prof. Jasna Tolmač, Chairman of the Organizing Committee
University of Novi Sad
Technical Faculty "Mihajlo Pupin"
Zrenjanin, Serbia

e-mail: iizs@tfzr.rs

Jasna Tolmač

Signature



TECHNICAL FACULTY "MIHAJLO PUPIN" ZRENJANIN,
UNIVERSITY OF NOVI SAD,
REPUBLIC OF SERBIA



CONFERENCE AGENDA

Venue:

Technical Faculty "Mihajlo Pupin" Zrenjanin,
October, 3-4th, 2024.

Thursday, 03.10.2024.	
15.00 - 17.00h	Registration
19.00h	Welcoming cocktail
Friday, 04.10.2024.	
9.00 – 10.00h	<i>Registration</i>
10.00 – 10.30h <u>36</u>	<i>OPENING of the XIV International conference on Industrial Engineering and Environment Protection</i> Ph.D Milan Nikolić, Dean of the TF “Mihajlo Pupin” Ph.D Jasna Tolmač, President of the Organizing Committee
PLENARY SESSION	
10.30 -11.30h <u>35</u>	Chairs: Slavica Prvulović, Jasna Tolmač
	EXAMINATION OF THE SAMPLE PROPERTIES MADE BY THE ADDITIVE Mirko Karakašić
	EVALUATING MICROPOLLUTANTS IN THE DANUBE RIVER: ASSESSING CONCENTRATIONS AND ENVIRONMENTAL IMPACT Marija Perović
11.30 - 12.00h	<i>Coffee break</i>
12.00 - 13.00h	ORAL/POSTER PRESENTATION
SESSION 1 (Chairs: Ljiljana Radovanović, Borivoj Novaković)	
12.00 - 13.00h <u>36</u>	Mechanical Engineering
	Energetics and Process Technique
	Designing and Maintenance
	Oil and gas engineering
	Engineering Management

SESSION 2 (Chairs: Višnja Mihajlović, Jovana Čugalj)	
12.00-13.00h	Health and Environmental Protection
<u>35</u>	Environmental Management and Occupational Safety
13.00 - 14.00h	<i>Lunch break</i>
14.00 - 14.30h	<i>Conclusions of the conference and closing ceremony</i>

ORAL/POSTER PRESENTATION

Session 1. Mechanical Engineering		
FREE VIBRATION ANALYSYS OF A BEAM RESTING ON WINKLER ELASTIC FOUNDATION THROUGH THE SUMUDU TRANSFORM METHOD FLUID	Svetlana Lilkova-Markova, Dimitar Lolov	University of Architecture, Civil Engineering and Geodesy, Faculty of Hydraulic Engineering, Sofia, Bulgaria
DEVELOPMENT OF A MODEL FOR ASSESSING VIBRATION RISK LEVELS IN HYDROPOWER PLANT TECHNICAL SYSTEMS	Slobodan Juric, Slavica Prvulovic, Jasna Tolmac, Uros Sarenac, Ljubisa Josimovic, Milos Josimovic	High school "CEPS-Center for Business Studies" Kiseljak, Bosnia and Herzegovina
ARTIFICIAL INTELLIGENCE IN FUNCTION OF IMPROVING PRODUCT FUNCTIONALITIES	Rade Dragović, Milada Novaković, Zoran Bakić, Marija Matotek Anđelić, Igor Kostovski, Valentina Mladenović	Institute for standards and technology, Belgrade, Serbia, Technical College of Applied Sciences, Zrenjanin, Serbia, Ministry of Economy, Belgrade, Serbia, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
THE ROLE OF COOLANT IN THE ENERGY BALANCE OF INTERNAL COMBUSTION ENGINES	Juraj Marković, Hrvoje Glavaš, Mirko Karakašić, Eleonora Desnica	Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, Osijek, Croatia, University of Slavonski Brod, Mechanical Engineering Faculty, Slavonski Brod, Croatia, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
EXAMINATION OF THE SAMPLE PROPERTIES MADE BY THE ADDITIVE	Mirko Karakašić	University of Slavonski Brod, Mechanical Engineering Faculty, Slavonski Brod, Croatia
PRODUCT DEVELOPMENT OF AN INDUSTRIAL CONTROL SYSTEM FOR ROTOR WITH A FOCUS ON DESIGN FEATURES	Jure Marijić, Ivan Grgić, Marko Vilić, Mirko Karakašić, Željko Ivandić	University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod, Slavonski Brod, Croatia
THE ROLE OF CERIUM AND PRASEODIUM AS RARE-EARTH ELEMENTS IN FILLER METAL FOR BRAZING DIAMOND – AN OVERVIEW	Zoran Karastojković, Jasmina Pekez, Radiša Perić	Society for Ethics and Evaluation in the Arts and Sciences, 11000 Belgrade, Serbia, Technical Faculty, University of Novi Sad, 22000 Zrenjanin, Serbia "Perić&Perić"d.o.o., Dunavska 114-116, 12000 Požarevac, Serbia

<p>MECHANICAL CENTRIFUGATION AND PYROLISIS AS A COMBINED PROCESS FOR EFFICIENT MANAGEMENT OF OIL REFINERY SLUDGE</p>	<p>Srđan Kovačević, Nikolina Tošić, David Mitrinović, Marko Muhadinović, Galina Ilinykin, Natalia Sliusar</p>	<p>University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia Institute for the Development of Water Resources “Jaroslav Černi”, Belgrade, Serbia Lafarge BFC Srbija, d.o.o. Perm National Research Polytechnic University, Environmental Protection Department, Perm, Russia</p>
<p>THE INFLUENCE OF THE LAYER HEIGHT ON THE HARDNESS OF THE TPU PLASTIC SPECIMEN MADE BY 3D PRINTING</p>	<p>Dušan Jovanić, Eleonora Desnica, Dušan Malić</p>	<p>Technical College of Applied Sciences, Zrenjanin, Serbia University of Novi Sad, Technical Faculty “Mihajlo Pupin“, Zrenjanin, Serbia</p>
<p>EVALUATION OF THE TECHNOLOGICAL EFFECTS OF CELLULAR MANUFACTURING FOR A GROUP OF PRODUCTS</p>	<p>Dejan Lukic, Mijodrag Milosevic, Ahmet Cekic, Maida Cohodar Husic, Djerzija Begic-Hajdarevic, Dejan Bozic</p>	<p>University of Novi Sad, Faculty of Technical Sciences, DPE, Novi Sad, Serbia University of Sarajevo, Faculty of Mechanical Engineering, Sarajevo, BiH</p>
<p>THE MECHANICAL PROPERTIES OF A CIRCULAR CROSS-SECTION COLUMN MADE OF COMPOSITE MATERIAL PRODUCED USING A NEW MIXED PLASTIC RECYCLING TECHNOLOGY</p>	<p>Ljubica Lazić Vulićević, Danijela M. Jašin, Aleksandar Rajić, Valentina Mladenović, Ivan Palinkaš</p>	<p>Technical College of Applied Sciences, Zrenjanin, Serbia University of Novi Sad, Technical Faculty “Mihajlo Pupin“, Zrenjanin, Serbia</p>
<p>STRESS ANALYSIS OF CRANE SHACKLE USING FEM</p>	<p>Srđan Samardžic, Spasoje Trifković, Miroslav Milutinović</p>	<p>University of East Sarajevo, Faculty of Mechanical Engineering, Republic of Srpska, Bosnia and Herzegovina</p>
<p>BIOMIMETIC APPLICATIONS IN FLUID MECHANICS: FROM NATURE-INSPIRED DESIGNS TO TECHNOLOGICAL ADVANCEMENTS</p>	<p>Murat Ispir, Muharrem Hilmi Aksoy</p>	<p>Konya Technical University, Faculty of Engineering and Natural Science, Konya, Türkiye</p>

<p>THE DEVIATION BETWEEN INJECTED MOLDED PLASTIC PART AND FDM MANUFACTURED PART</p>	<p>Ivan Matin, Branko Štrbac, Miloš Ranisavljev, Miodrag Hadžistević, Đorđe Vukelić</p>	<p>University of Novi Sad, Faculty of Technical Sciences, Department of Production Engineering, Novi Sad, Serbia</p>
<p>ALGEBRAIC DIAMETER PROPORTION EXPRESSIONS DERIVED AND EXAMINED FOR EQUAL FLOW DISTRIBUTION BY MANIFOLD NOZZLE COUPLE</p>	<p>Eyüb Canli</p>	<p>Mechanical Engineering Department, Technology Faculty, Selcuk University, Konya, Türkiye</p>
<p>OPTIMAL LQR CONTROL OF A PENDULUM BASED OVERHEAD CRANE USING THE WHALE OPTIMIZATION ALGORITHM</p>	<p>Abdullah Çakan</p>	<p>Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Mechanical Engineering, Konya, Turkey</p>
<p>ANALYSIS OF THE SYSTEM FOR ACTIVE VIBRATION REDUCTION DURING WHEEL LOADER MOVEMENT</p>	<p>Jovan Pavlović, Dragoslav Janošević, Vesna Jovanović</p>	<p>University of Niš, Faculty of Mechanical Engineering, Niš, Serbia</p>
<p>THE DIGITAL FACTORY–PRESENT AND FUTURE</p>	<p>Stanko P. Stankov</p>	<p>University of Niš, Faculty of Electronic Engineering, Niš, Serbia</p>
<p>A SUPERVISORY CONTROL OF WATER SUPPLY SYSTEM</p>	<p>Stanko P. Stankov</p>	<p>University of Niš, Faculty of Electronic Engineering, Niš, Serbia</p>
<p>THE EXAMINATION OF OPERATIONAL CONDITION THROUGH THE VOLUMETRIC EFFICIENCY OF AN AXIAL PISTON PUMP</p>	<p>Borivoj Novaković, Luka Đorđević, Ljiljana Radovanović, Mihalj Bakator, Milan Marković, Stefan Ugrinov, Mića Đurđev</p>	<p>University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia</p>
<p>AUTOMATED DECISION SUPPORT SYSTEMS</p>	<p>Sondra Preascilla Ioana Vacarescu, Nicolae Paraschiv, Flavius-Maxim Petcuț</p>	<p>Petroleum-Gas University of Ploiesti, Romania Continental Automotive Romania Aurel Vlaicu University of Arad, Romania</p>

<p align="center">DEVELOPMENT OF SUPPORT VECTOR MACHINE MODEL FOR CHIP FORM CLASSIFICATION IN TURNING OF POM-C</p>	<p align="center">Miloš Madić, Milan Trifunović, Marko Kovačević</p>	<p align="center">University of Niš, Faculty of Mechanical Engineering in Niš, Niš, Serbia Independent researcher, University of Niš, Niš, Serbia</p>
<p align="center">DEVELOPMENT OF A MODEL FOR ASSESSING VIBRATION RISK LEVELS IN HYDROPOWER PLANT TECHNICAL SYSTEMS</p>	<p align="center">Slobodan Juric, Slavica Prvulovic, Jasna Tolmac, Uros Sarenac, Ljubisa Josimovic, Milos Josimovic</p>	<p align="center">University of Architecture, Civil Engineering and Geodesy, Faculty of Hydraulic Engineering, Sofia, Bulgaria</p>
<p align="center">Session 1. Energetics and Process Technique</p>		
<p align="center">RISK ANALYSIS USING THE INTEGRATED FTA AND FMEA MODEL ON THE EXAMPLE OF A BIOGAS PLANT</p>	<p align="center">Jovana Radnović, Vesna Makitan</p>	<p align="center">University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia</p>
<p align="center">LOCALIZED STATES OF BASIC ELEMENTARY CHARGES IN ULTRATHIN CRYSTALLINE FILM-STRUCTURES</p>	<p align="center">Nikola R. Vojnović, Dušan I. Ilić, Jovan P. Štrajčić</p>	<p align="center">University of Novi Sad, Faculty of Technical Sciences, Trg D.Obradovića 6, 21.000 Novi Sad, Vojvodina – Serbia Academy of Sciences and Arts of the Republic of Srpska, Bana dr T.Lazarevića 1, 78.000 Banja Luka, Republic of Srpska, B&H</p>
<p align="center">APPLICATION OF STATISTICAL METHODS IN ORDER TO DETERMINE THE LEVEL OF ENERGY EFFICIENCY</p>	<p align="center">Čugalj Jovana, Pekez Jasmina, Stojanov Jelena</p>	<p align="center">University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia</p>
<p align="center">ANALYSIS OF A RESIDENTIAL PHOTOVOLTAIC SYSTEM</p>	<p align="center">Anca-Adriana Petcuț-Lasc, Valentina-Emilia Bălaș, Flavius-Maxim Petcuț</p>	<p align="center">Aurel Vlaicu University of Arad, Romania Petroleum-Gas University of Ploiesti, Romania</p>
<p align="center">Session 1. Designing and Maintenance</p>		
<p align="center">PRELIMINARY STUDY ON DRIVER POSTURE THROUGH NEW METHOD OF ANALYSIS</p>	<p align="center">Anca SABAU, Mihaela POPA, Gabriela STOIA, Timotei Bogdan BACOȘ, Adrian Eugen CIOABLĂ</p>	<p align="center">Faculty of Mechanical Engineering, University Politehnica Timisoara, Timisoara, Romania</p>

PROJECT MANAGEMENT AND MAINTENANCE OPTIMIZATION IN INDUSTRIAL TECHNICAL SYSTEMS	Peko Lakatuš	University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
Session 1. Oil and gas engineering		
OPTIMIZATION OF OIL PRODUCTION ON THE EXAMPLE OF LIBYA	Branislava Radišić, Snežana Komatina, Slavica Prvulović, Snežana Filip, Dragana Kovač	University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
POSSIBILITIES OF PURIFICATION OF OIL CONTAMINATED WATER USING PERLITE	Danijela Jašin, Milana Drašković, Milada Novaković	Technical College of Applied Studies, Zrenjanin, Serbia
ANALYSIS OF TEMPERATURE DROP AND HEAT LOSSES OF CRUDE OIL ALONG THE MAIN OIL PIPELINE	Jasna Tolmač, Slavica Prvulović, Saša Jovanović, Uroš Šarenac, Branislava Radišić	University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin University of Pristina, Faculty of Technical Sciences, Kosovska Mitrovica, 38220, Kosovo
Session 1. Engineering Management		
THE IMPORTANCE OF BUSINESS INCUBATORS FOR THE IMPLEMENTATION OF ENERGY MANAGEMENT	Vladimir Milošev, Rade Dragović, Igor Kostovski	University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
SUSTAINABLE SUPPLY CHAIN MANAGEMENT IN THE CONTEXT OF NATURAL RESOURCE CONSERVATION	Stefan Ugrinov, Sanja Stanisavljev, Mihalj Bakator, Edit Terek Stojanović, Mila Kavalić, Verica Gluvakov	University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
ARTIFICIAL INTELLIGENCE – AN ESSENTIAL FACTOR IN CORPORATE STRATEGIC COMMUNICATION	Zlatko Lacković, Milan Ivanović, Krešimir Lacković	Panon – think tank, Osijek, Croatia 2 Sveučilište Sjever - Koprivnica, Croatia
THE APPLICATION OF INDUSTRY 4.0 AMONG ENTREPRENEURS IN THE REPUBLIC OF SERBIA	Bojan Stankov, Sanja Stanisavljev, Mila Kavalić, Verica Gluvakov, Snežana Mirković	Hemofarm a.d. Hemofarm A.D., Beogradski put bb, 26300 Vršac, Srbija, Technical Faculty "Mihajlo Pupin", Zrenjanin, University of Novi Sad, Zrenjanin, Serbia, 5BB TRADE doo, Zrenjanin, Serbia

XIV International Conference - Industrial Engineering and Environmental Protection (IIZS 2024)

GREEN BEHAVIOR OF EMPLOYEES	Dragana Kovač, Edit Terek Stojanović, Mila Kavalić, Maja Gaborov, Melita Ćočkalo-Hronjec	University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia High school „Laza Kostic“, Novi Sad, Republic of Serbia
COMMISSIONING AND QUALIFICATION OF A PHARMACEUTICAL FACILITY	Ilija Tabašević, Dragan D. Milanović, Mirjana Misita	Hemofarm, Vršac, Serbia University of Belgrade, Faculty of Mechanical Engineering, Beograd, Serbia
CIRCULAR ECONOMY IN THE CONSTRUCTION SECTOR: THE SITUATION IN CROATIA	Držislav Vidaković, Marijana Hadzima- Nyarko, Laura Šoja	Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek, Osijek, Croatia Josip Juraj Strossmayer University of Osijek, Faculty of Economics and Business, Osijek, Croatia
INTRODUCING ISO 22301 INTO AN ESTABLISHED INTEGRATED MANAGEMENT SYSTEM (IMS)	Marija Perović, Marija Todorović	Jaroslav Černi Water Institute, Belgrade, Serbia
Session 2. Health and Environmental Protection		
VALIDATION OF SOME AIR POLLUTANT DISTRIBUTION MODELS	Stevo K. Jaćimovski, Dane Subošić, Jovan P. Štrajčić	University of Criminalistic and Police Studies, Zemun – Belgrade, Serbia Academy of Sciences and Arts of the Republic of Srpska, Banja Luka, B&H
EXPERIMENTAL STUDY OF FIRE HAZARDS FROM SMALL-SCALE METHANE FIRES	Milan Protić, Nikola Mišić, Ana Vukadinović, Jasmina Radosavljević, Miomir Raos	University of Niš, Faculty of Occupational Safety, Niš, Serbia
INTEGRATION OF CIRCULAR ECONOMY AND INDUSTRIAL ECOLOGY: PATHWAYS TO SUSTAINABLE INDUSTRIAL DEVELOPMENT	Vesna Drakulović, Višnja Mihajlović, Bogdana Vujić, Mića Đurđev, Milan Marković	Univesity of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia
METHODOLOGY OF DETERMINATION OF FIRE HAZARD ZONES IN THE HIGH-BAY WAREHOUSES	Goran Bošković, Višnja Mihajlović, Nikola Karanović, Natalija Nikolić, Zoran Čepić	Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, Kraljevo, Serbia Technical Faculty “Mihajlo Pupin”, University of Novi Sad, Zrenjanin, Serbia University of Aveiro, Portugal Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia

XIV International Conference - Industrial Engineering and Environmental Protection (IIZS 2024)

<p align="center">GIS AND REMOTE SENSING IN FOREST FIRE ANALYSIS IN SERBIA</p>	<p align="center">Natalija Nikolić, Jovana Čugalj, Vesna Drakulović</p>	<p align="center">Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia Technical Faculty “Mihajlo Pupin” Zrenjanin, University of Novi Sad, Serbia</p>
<p align="center">PTE DISTRIBUTION FACTOR AS AN INDICATOR OF URBAN SOIL POLLUTION</p>	<p align="center">Aleksandra Mihailović, Jordana Ninkov, Selena Samardžić, Savka Adamović Robert Lakatoš, Sofija M. Forkapić, Tomas Nemeš</p>	<p align="center">University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia, Institute of Field and Vegetable Crops, National Institute of the Republic of Serbia, Maksima Gorkog 30, Novi Sad, University of Novi Sad, Serbia Faculty of Sciences, Novi Sad, Serbia</p>
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Paper Status	Accepted
Paper title	EVALUATING MICROPOLLUTANTS IN THE DANUBE RIVER: ASSESSING CONCENTRATIONS AND ENVIRONMENTAL IMPACT
Author(s)	Marija Perović

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EVALUATING MICROPOLLUTANTS IN THE DANUBE RIVER: ASSESSING CONCENTRATIONS AND ENVIRONMENTAL IMPACT

Keynote paper

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Abstract: Freshwater pollution poses a significant global challenge, largely driven by the continuous release of synthetic organic substances into the environment. This persistent contamination underscores the urgent need for a thorough understanding of the chemical status of Earth's surface waters. Even trace amounts (ng/L; µg/L) of these substances, known as micropollutants, can accumulate in aquatic ecosystems, posing risks to both biodiversity and human health. This research examines key water quality parameters of the Danube River in Serbia, focusing on the prevalence of micropollutants within a river basin that spans 92% of the country's land area and 10% of the entire Danube basin. It also provides an overview of existing regulatory frameworks that set limit values for these contaminants. By reviewing official data on hazardous substances and other pollutants concentration, the study provides valuable insights into water quality challenges and offers guidance for future management strategies aimed at addressing micropollutants.

Key words: Danube, micropollutants, hazardous substances

INTRODUCTION

The entire life cycle of a product from production and processing to use and disposal can lead to the release of hazardous substances. These include household and industrial chemicals, pollutants from transportation (such as hydrocarbons and heavy metals), as well as pesticides widely used in agriculture and along roads and railways [1]. Micropollutants (MPs) are found in trace amounts across various environmental compartments and organisms. They include a wide range of contaminants, some of which are classified as priority substances (PSs) under environmental regulations due to their persistence, toxicity, and potential to bioaccumulate, posing significant risks to human health and the environment. Key groups of MPs include pharmaceuticals, personal care products, pesticides, trace metals, persistent organic pollutants, micro- and nanoplastics, artificial sweeteners, and other compounds that pose potential threats to ecological systems [2]. Urban wastewater treatment plants are significant point sources of hazardous substances, as conventional treatment methods, such as coagulation, sedimentation, sand filtration, chlorination, biological degradation, and UV irradiation, often fail to remove MPs, including Per- and Polyfluoroalkyl Substances (PFAS) [3,4]. Agricultural activities are a major source of MPs, primarily due to the extensive use of pesticides, which contaminate surface waters through runoff, leaching, and erosion, and reach groundwater through permeable soils and water percolation. The most studied PSs worldwide, are pesticides, including atrazine, simazine, chlorpyrifos, terbutryn, diuron, and alachlor [5]. Although soil can absorb and retain metals, emissions from agriculture, such as cadmium from phosphate fertilizers, zinc from animal feed, and copper used in feed, treatments, and disinfection, remain significant environmental concerns. PFAS comprise a broad range of over 4,700 synthetic compounds, attracting increasing attention due to their ubiquity in both the environment and human populations worldwide. Perfluorooctanoic acid (PFOA) and Perfluorooctane sulfonate (PFOS), are among the most widely used, frequently detected, and extensively studied PFAS in the environment [6]. They are used in cosmetics, textiles for stain and water repellence, adhesives, fire-fighting foams, paper products. Additionally, PFAS are found in semiconductors, lubricants, coating additives, cookware and food packaging, surfactants, agricultural applications, pesticides, and as erosion inhibitors in aviation [7-9]. Their presence in surface and groundwater highlights the connection between human activity and the hydrological cycle [10]. Although many hazardous substances have been banned or

phased out, surface and groundwater contamination persist due to their past use and ongoing illegal applications. This is evidenced by the continued detection of notable concentrations of these substances and their metabolites in the environment [11,12].

Legislative Framework for Pollutants and Hazardous Substances in water

Since its inception in 2000, the Water Framework Directive (WFD) has been the cornerstone of water protection in Europe, alongside the Environmental Quality Standards Directive (EQSD) and the Groundwater Directive. The WFD aims to protect inland surface waters, transitional waters, coastal waters, and groundwater by reducing discharges and emissions of priority substances (PS) and phasing out or minimizing those of priority hazardous substances (PHSs) through targeted regulations and benchmarks. The WFD identifies surface water pollutants of significant EU-wide concern as PS, including PHS listed in Annex X, with environmental standards set by the EQSD. Article 2 of the WFD defines hazardous substances as those that are toxic, persistent, and prone to bioaccumulation, or that raise similar concerns. Article 4 outlines the environmental objectives, requiring Member States to implement measures to reduce pollution from PS and to phase out emissions, discharges, and losses of PHS. The WFD requires EU Member States to closely monitor potential pollutants through a Watch List (WL) for surface waters [13]. The monitoring of PSs and contaminants of emerging concern is governed by Directive 2013/39/EU and the updated WL under Decision (EU) 2022/1307/EU. The WFD requires that for international river basins extending beyond EU borders, a single river basin management plan should be developed. Under the WFD, pollution from hazardous substances is a critical water quality issue that must be addressed in the Danube River Basin (DRB). This obligation also extends to non-EU Member States, which have committed to achieving similar objectives under the framework of the International Commission for the Protection of the Danube River (ICPDR). In 2000, ICPDR countries, including non-EU states, agreed to implement this directive across the entire Danube basin. The Federal Republic of Yugoslavia ratified the Convention on the Protection and Sustainable Use of the Danube River in 2003 and enacted the corresponding law. In the same year, Serbia, as part of the State Union of Serbia and Montenegro, joined the ICPDR.

In the Republic of Serbia within the Water Law ("Official Gazette of the Republic of Serbia", No. 30/2010, 93/2012, 101/2016, 95/2018, and 95/2018 - amended law) the Priority substances are those identified as posing significant risks to the aquatic environment or to other areas through it, as determined by specific regulations. This category includes "priority hazardous substances," which are selected priority substances that present an increased risk to human health or the environment. In Serbia the list of priority and priority hazardous substances and its Average annual concentrations (AAC) and Maximum allowable concentrations (MAC) are defined in Regulation on limit values of priority and priority hazardous substances that pollute the surface waters and deadlines for their achievement ("Official Gazette of the Republic of Serbia", No. 24/2014). This list is in accordance with Annex X of the WFD. In addition to the aforementioned, the Regulation on Limit Values of Pollutants in Surface and Groundwater and Sediment, and Deadlines for Their Achievement ("Official Gazette of the RS", No. 50/2012) defines the limit values of pollutants in surface and groundwater, as well as in sediment, along with the deadlines for achieving these values.

Around 90% of Serbia's renewable water resources come from outside its borders, emphasizing the crucial need for international cooperation [14]. Serbia, spanning 88,499 km², is predominantly within the Danube Basin, which covers 92% of its land and 10% of the total basin area [14]. Municipal sources are the primary contributors to pollution in Serbia, while emissions from industry are considered the primary source of hazardous substances in Serbia [14,15]. Agricultural pollution mainly stems from livestock farming, with minor contributions from mineral fertilizers used on non-irrigated lands [14].

This research aims to assess the presence and concentration of micropollutants, in the Serbian section of the Danube River using official data from the National Surface Water Quality Monitoring Program of the Serbian Environmental Protection Agency (SEPA). The scope includes identifying which priority substances and pollutants are detectable in the Danube section in Serbia.

MATERIAL AND METHODS

In this study, selected water quality data for the Danube River along its course through Serbia were analyzed, sourced from the National Surface Water Quality Monitoring Program of the Serbian Environmental Protection Agency (SEPA). From the SEPA's results of the examination of physical-chemical, chemical, and microbiological parameters for assessing the status of surface water the selected physical-chemical and chemical parameters of surface water, priority and priority hazardous substances and other pollutants were analyzed. Basic descriptive statistics for selected water quality parameters over a seven-year period (2016–2022), with monthly sampling frequency, was done. A total of 576 samples collected from Bezdán, Bogojevo, Novi Sad, Zemun, Smederevo, Banatska Palanka, and Tekija were all analyzed (Fig. 1).

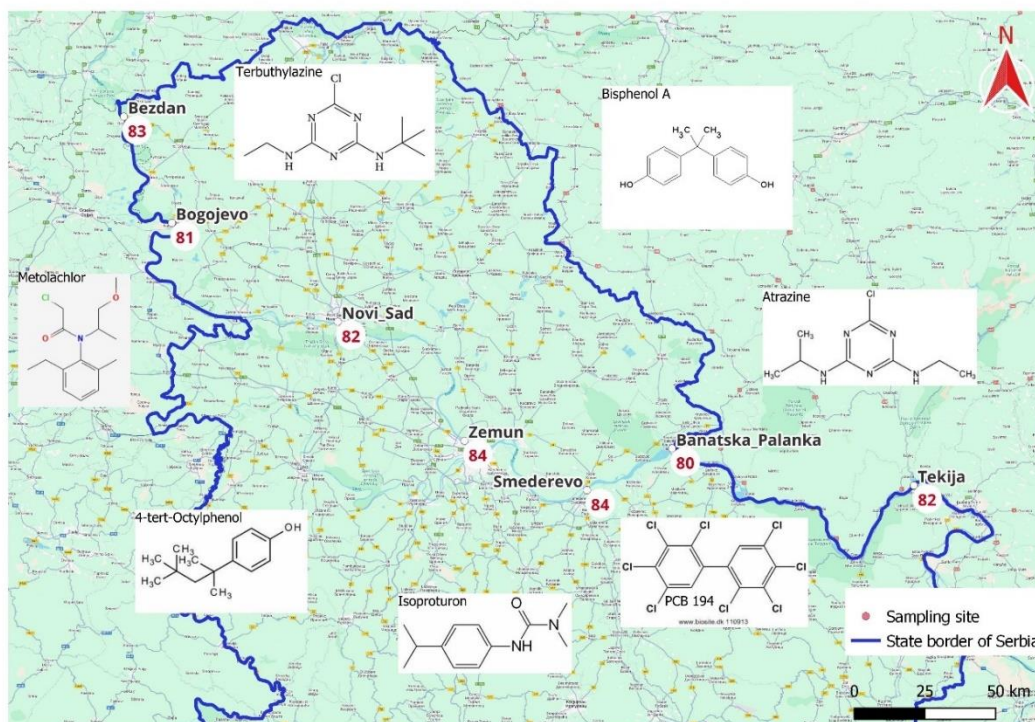


Fig. 1. Sampling Locations with Marked Number of Samples

RESULTS AND DISCUSSION

Table 1 presents the basic descriptive statistics for key water quality parameters specific to the Serbian section of the Danube River, providing an overall summary for all sampling locations combined. The range of electrical conductivity of water is from 291.0 $\mu\text{S}/\text{cm}$ to 600.0 $\mu\text{S}/\text{cm}$, while median values (50th percentile) for NH_4^+ , NO_3^- and Cl are 0.08 mgN/l, 1.01 mgN/l and 19.95 mg/l, respectively. The range of quantified boron is moderate, from below limit of quantification <10 $\mu\text{g}/\text{l}$ to 253.5 $\mu\text{g}/\text{l}$. Seventy-five percent of the analyzed samples exhibit a chemical oxygen demand of up to 4.40 mg/l, indicating a moderate organic load in analysed water.

Although the measured range of total organic carbon (TOC) is quite broad, 75% of the samples show quantified concentrations of up to 4.80 mg/l. Additionally, the Biochemical Oxygen Demand (BPK5), which reflects the oxygen consumption by bacteria during the decomposition of organic matter in the water, averages 2.12 mg/l, with values ranging from a minimum of 0.60 mg/l to a maximum of 5.60 mg/l. This indicates that organic pollution is present but remains at manageable levels.

Table 2 provides basic descriptive statistics for selected metals, including cadmium (Cd), lead (Pb), nickel (Ni), zinc (Zn), copper (Cu), chromium (Cr), and metalloid arsenic (As). The largest concentration ranges are observed for Cu, Zn, and Ni. Total Cd was found at a mean concentration of 0.05 µg/l, with values ranging from less than 0.02 µg/l to 1.00 µg/l, indicating minimal contamination in most samples. Total Ni exhibited a mean concentration of 7.52 µg/l, with a notable range from less than 0.5 µg/l to 412.20 µg/l, suggesting sporadic pollution sources. Total Pb had a mean concentration of 1.39 µg/l, ranging from less than 0.5 µg/l to 30.10 µg/l, indicating generally low levels but highlighting potential localized pollution. Total Cr concentrations ranged from less than 0.5 µg/l to 58.00 µg/l, suggesting predominantly low levels; Zn and Cu exhibited significant concentration ranges, from less than 10 µg/l to 671.70 µg/l and from less than 1 µg/l to 834.30 µg/l, respectively, indicating influences from anthropogenic sources. As (total) was found with a mean concentration of 5.99 µg/l, ranging from 0.50 µg/l to 361.10 µg/l. The higher concentrations of arsenic raise health concerns and underscore the need for more detailed ongoing surveillance. While most metals are present at low concentrations, the significant variability, particularly in nickel, zinc, copper, and arsenic levels, emphasizes the necessity for continuous monitoring and more detailed data assessments to identify potential pollution sources and protect water quality.

Table 3 lists priority and priority hazardous substances detected above the limit of quantification (LOQ) in over 30% of samples, along with their applicable limit values as defined in the Regulation on Limit Values of Priority and Priority Hazardous Substances Polluting Surface Waters and Deadlines for Their Achievement ('Official Gazette of RS,' No. 24/2014). It should be noted that not all substances have prescribed limit values. Among these, the compounds identified include industrial chemicals such as organic derivatives of phenol (para-tert-octylphenol), PCB 194, and bisphenol A and pesticides (atrazine, terbuthylazine, metolachlor, and isoproturon) (Table 3). The same Regulation prescribes an AAC of 6.5×10^{-4} µg/L and a MAC of 36 µg/L for PFOS and its derivatives, but these compounds are not part of the regular monitoring in Serbia. Table 4 presents priority substances, metals cadmium (Cd), lead (Pb), and nickel (Ni) along with their limit values as regulated by the Regulation on Limit Values of Priority and Hazardous Substances Polluting Surface Waters and Deadlines for Their Achievement ("Official Gazette of RS," No. 24/2014). Table 5 outlines the prescribed limit values for polluting substances in surface waters, specifically chromium (Cr), copper (Cu), zinc (Zn), and metalloid arsenic (As). These limit values are established by the Regulation on limit values of pollutants in surface and groundwater and sediment and on deadlines for their achievement ("Official Gazette of the RS," No. 50/2012). Priority substances quantified in more than 30% of the measurements above the LOQ, which are part of both operational and surveillance monitoring (excluding metals), were selected for presentation and further discussion.

Organic derivatives of phenol, like Para-tert-Octylphenol (OP), are hazardous endocrine-disrupting compounds with significant environmental and health impacts. Primarily used in phenolic resin and lacquer production, OP exhibits weak estrogen-like activity and has been found in various environmental compartments, including water, phytoplankton, zooplankton, mussels, and fish tissues. Its concentration, influenced by diet and habitat, suggests bioaccumulation potential [16]. OP disrupts hormone regulation, affecting reproduction, growth, and behavior, and can mimic the sex hormone 17β-estradiol, leading to feminization in aquatic life and developmental issues in humans, including cancers of the sex organs [16].

The presence of alkylphenolic compounds along the Danube River highlights widespread wastewater contamination with varying impacts [17].

PCB 194, a synthetic organic compound classified as 2,2',3,3',4,4',5,5'-octachlorobiphenyl, belongs to the polychlorinated biphenyl (PCB) group. Despite being banned decades ago, PCBs persist in the environment due to their bioaccumulative properties and ongoing releases from historical industrial activities, spills, and thermal processes [18]. They can exist in vapor or particulate form and disrupt hormonal, reproductive, immune, and endocrine functions, leading to severe health issues, including cancer, birth defects, and cognitive impairments. Bisphenol A (BPA; 4,4'-dihydroxy-2,2-diphenylpropane) is a widely used chemical in the production of polycarbonate plastics, epoxy resins, and as a non-polymer additive in PVC. It can be found in products like shatterproof windows, eyewear, water bottles, and epoxy-coated metal food cans. While BPA is rapidly metabolized and excreted in urine, biomonitoring studies have detected unconjugated BPA, indicating ongoing internal exposure risks [19]. Human exposure primarily occurs through the consumption of food and bottled mineral water.

Atrazine, a chlorinated herbicide from the triazine class, is mainly used to control broadleaf weeds in crops like maize, soybean, and sugarcane, as well as in turf areas. As an endocrine disruptor, it can cause reproductive issues, behavioral changes, and impaired fetal growth, and is linked to birth defects and various cancers, including non-Hodgkin lymphoma and breast cancer [20]. In aquatic environments, atrazine degrades into metabolites such as deethylatrazine (DEA), deisopropylatrazine (DIA), and deethyl-deisopropylatrazine (DEIA). Given atrazine's half-life in water of 105 to over 200 days, its detection in the Danube suggests ongoing use, despite the ban on atrazine-containing herbicides in Serbia since 2007. This ban was implemented by the Plant Protection Administration of the Ministry of Agriculture, Forestry, and Water Management [21].

Terbutylazine (TBA) has largely replaced atrazine in several EU countries and is now a widely used pesticide and one of the most frequently detected in continental and coastal waters with its metabolite desethylterbutylazine (DET) being prevalent in EU aquifers [22]. DET is more water-soluble and binds less to organic matter, increasing the risk of groundwater contamination. Both TBA and DET are emerging chemicals of concern due to their persistence and toxicity to aquatic life, as well as their significant endocrine-disrupting effects on wildlife and humans. Metolachlor, a selective herbicide for annual grass weeds and certain broadleaf species, raises concerns due to evidence of bioaccumulation in edible fish and negative impacts on growth and development. Isoproturon, another selective herbicide, is used for controlling broadleaf weeds and grasses in crops. It has low acute toxicity, but related chemicals like monolinuron and linuron can cause developmental malformations. Data on environmental levels of isoproturon are limited, but exposure to the general population appears minimal, with health effects mainly studied in occupational settings.

The selected parameters represent micropollutants, detected above the limit of quantification in more than 30% of cases, providing insights into which substances are present in the Danube River. It is important to emphasize that these substances have not been analyzed in terms of whether the quantified average annual concentration or maximum concentrations exceed the prescribed limit values, as the presented data processing (overall summary for all sampling locations combined) does not correspond to that type of interpretation. The study aimed to identify which substances are present above the quantification limit, indicating their actual occurrence.

Table 1. Basic Descriptive Statistics of selected parameters for the section of the Danube River flowing through Serbia (based on SEPA data, 2016–2022)

	Flow	Susp.*	pH	Ec**	NH ₄	NO ₃	Cl	B	COD KMnO ₄	BPK ₅	TOC	
Unit	m ³ /s	mg/l	/	μS/cm	mgN/l	mgN/l	mg/l	μg/l	mg/l	mg/l	mg/l	
No of samples	342	570	568	576	576	576	576	372	575	571	500	
Mean	2932	20.4	8.09	402.9	0.10	1.16	20.60	31.00	3.90	2.12	4.11	
Std. dev.	1371	20.3	0.21	54.4	0.07	0.55	5.16	23.17	1.07	0.75	1.14	
Min.	1020	<4	7.08	291.0	<0.02	0.14	5.40	<10	1.29	0.60	1.30	
Max.	9610	178.0	8.80	600.0	0.35	3.24	41.98	253.50	12.06	5.60	11.00	
Percentile	25	1975	7.0	7.96	359.0	0.04	0.80	16.80	19.43	3.20	1.60	3.40
	50	2700	15.0	8.09	393.5	0.08	1.01	19.95	26.40	3.70	2.10	4.00
	75	3420	27.0	8.20	442.0	0.14	1.40	23.38	37.08	4.40	2.50	4.80

Susp.* - suspended solids
 Ec** - electrical conductivity

Table 2 Basic Descriptive Statistics of selected metals (and metalloid As) for the section of the Danube River flowing through Serbia (based on SEPA data, 2016–2022)

	Cd	Cd diss	Ni	Ni diss	Pb	Pb diss	Cr	Cr diss	Zn	Zn diss	Cu	Cu diss	As	As diss	
Unit	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	
No of samples	399	438	399	438	399	440	398	436	398	407	399	437	398	433	
Mean	0.05	0.03	7.52	3.63	1.39	0.43	1.76	0.74	52.69	30.97	15.22	7.63	5.99	3.02	
St.dev.	0.08	0.09	23.23	5.87	1.86	0.65	3.93	1.95	79.27	54.10	46.43	14.78	32.27	17.44	
Min.	<0.02	<0.02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	<10	<1	<1	0.50	<0.5	
Max.	1.00	1.76	412.20	74.40	30.10	9.30	58.00	36.80	671.70	423.00	834.30	148.60	361.10	287.80	
Percentile	25	<0.02	<0.02	1.90	1.20	0.60	<0.5	0.70	<0.5	15.40	<10	4.70	2.30	1.50	1.20
	50	0.03	0.02	2.90	1.90	1.10	<0.5	1.00	<0.5	26.10	14.00	6.80	3.80	1.80	1.50
	75	0.06	0.03	6.45	3.60	1.60	<0.5	1.58	0.70	51.15	26.25	12.35	6.70	2.30	2.00

Diss – dissolved

Table 3 Statistical metrics for analysing priority and priority hazardous substances and other pollutants quantified above quantification limit (LOQ) in more than 30% of samples in Danube River in Serbia (based on SEPA data, 2016–2022)

Parameter	Unit	No of samples	No of measurements above LOQ	Percentage of Measurements Above LOQ of Total Measurements	Maximum quantified concentration	Priority Hazardous Substances (PHS)*	Prescribed AAC (µg/l) *	Prescribed MAC (µg/l) *
Para-tert-Octylphenol	µg/l	434	139	32	0.162	No	0.1	/
Atrazine	µg/l	434	220	51	0.161	No	0.6	2
Desethylterbutylazine	µg/l	434	252	58	0.045	Not Covered by Regulation*	Not Covered by Regulation*	Not Covered by Regulation*
Terbutylazine	µg/l	434	360	83	1.672	Not Covered by Regulation*	Not Covered by Regulation*	Not Covered by Regulation*
Metolachlor	µg/l	432	354	82	0.71	Not Covered by Regulation*	Not Covered by Regulation*	Not Covered by Regulation*
Isoproturon	µg/l	434	223	51	0.02	No	0.3	1
PCB-194	µg/l	98	89	91	117.6	Not Covered by Regulation*	Not Covered by Regulation*	Not Covered by Regulation*
Bisphenol A	µg/l	297	117	39	0.165	Not Covered by Regulation*	Not Covered by Regulation*	Not Covered by Regulation*

* Regulation on limit values of priority and priority hazardous substances that pollute the surface waters and deadlines for their achievement ("Official Gazette of RS," No. 24/2014)

Table 4 Prescribed limit values According to Regulation on limit values of priority and priority hazardous substances that pollute the surface waters and deadlines for their achievement "Official Gazette of RS," No. 24/2014 ("Official Gazette of RS," No. 24/2014)

Parameter	Unit	Priority Hazardous Substances (PHS)	Prescribed Average Annual Concentration (AAC) (µg/l)	Prescribed Maximum Allowable Concentration (MAC) (µg/l)
Cd and its compounds (depending on water hardness* class)	µg/l	Yes	<0,08 (class 1) 0,08 (class 2) 0,09 (class 3) 0,15 (class 4) 0,25 (class 5)	<0,45 (class 1) 0,45 (class 2) 0,6 (class 3) 0,9 (class 4) 1,5 (class 5)
Pb and its compounds**	µg/l	No	1.2	14
Ni and its compounds	µg/l	No	4	34

*For cadmium and its compounds, the limit value varies depending on the hardness of water, which is categorized into five classes (Class 1: <40 mg CaCO₃/L, Class 2: 40 to <50 mg CaCO₃/L, Class 3: 50 to <100 mg CaCO₃/L, Class 4: 100 to <200 mg CaCO₃/L, and Class 5: ≥200 mg CaCO₃/L)

** These values for the environmental quality standard indicate the concentrations of substances that are bioavailable.

Table 5 Prescribed limit values of polluting substances in surface waters according to Regulation on limit values of pollutants in surface and groundwater and sediment and on deadlines for their achievement ("Official Gazette of the RS," No. 50/2012)

Parameter	Unit	Limit Values ⁽¹⁾				
		Class I ⁽²⁾	Class II ⁽³⁾	Class III ⁽⁴⁾	Class IV ⁽⁵⁾	Class V ⁽⁶⁾
Cr (total)	µg/l	25 (or NL)	50	100	250	>250
Cu	µg/l	5 (T=10) 22 (T=50) 40 (T=100) 112 (T=300)	5 (T=10) 22 (T=50) 40 (T=100) 112 (T=300)	500	1000	>1000
Zn	µg/l	30 (T=10) 200 (T=50) 300 (T=100) 500 (T=500)	300 (T=10) 700 (T=50) 1000 (T=100) 2000 (T=500)	2000	5000	>5000
As	µg/l	<5 or NL	10	50	100	>100

(1) Unless otherwise specified, the values are expressed as total concentrations in the sampled specimen

(2) The description of this class corresponds to an excellent ecological status according to the classification provided in the regulation that stipulates the parameters for ecological and chemical status for surface waters. Surface waters belonging to this class ensure, based on the limit values of quality elements, conditions for the functioning of ecosystems, the life and protection of fish (salmonids and cyprinids), and can be used for the following purposes: drinking water supply with prior treatment through filtration and disinfection, bathing and recreation, irrigation, and industrial use (process and cooling water).

(3) The description of this class corresponds to a good ecological status according to the classification provided in the regulation that stipulates the parameters for ecological and chemical status for surface waters. Surface waters belonging to this class ensure, based on the limit values of quality elements, conditions for the functioning of ecosystems, the life and protection of fish (cyprinids), and can be used for the same purposes and under the same conditions as surface waters belonging to Class I.

(4) The description of this class corresponds to a moderate ecological status according to the classification provided in the regulation that stipulates the parameters for ecological and chemical status for surface waters. Surface waters belonging to this class ensure, based on the limit values of quality elements, conditions for the life and protection of cyprinids and can be used for the following purposes: drinking water supply with prior treatment through coagulation, flocculation, filtration, and disinfection, bathing and recreation, irrigation, and industrial use (process and cooling water).

(5) The description of this class corresponds to a poor ecological status according to the classification provided in the regulation that stipulates the parameters for ecological and chemical status for surface waters. Surface waters belonging to this class can be used for the following purposes based on the limit values of quality elements: drinking water supply with the application of a combination of previously mentioned treatments and enhanced treatment methods, irrigation, and industrial use (process and cooling water).

(6) The description of this class corresponds to a bad ecological status according to the classification provided in the regulation that stipulates the parameters for ecological and chemical status for surface waters. Surface waters belonging to this class cannot be used for any purpose.

T - water hardness (mg/L CaCO₃)

NL – natural level (According to the Regulation on the limit values of polluting substances in surface and groundwater and sediment and deadlines for their achievement ("Official Gazette of the Republic of Serbia," No. 50/2012), is the concentration of a polluting substance that corresponds to a state of groundwater bodies whose undisturbed conditions are not subject to changes resulting from anthropogenic effects, or where such changes are very minor).

CONCLUSION

Potential pollution sources for aquatic environments include industrial activities, mines, tailings, waste disposal sites, landfills, wastewater and agricultural pesticide use. Despite the recognized significance of these pollutants in water management issues within Serbia, systematic data collection regarding these sources and their contributions to water quality is lacking [15]. Thus, it is crucial to intensify research efforts and improve monitoring practices to accurately assess the pressures exerted by these sources on water bodies. This study analyzed the quality of 576 water samples collected from various locations along the Danube River in Serbia, including Bezdán, Bogojevo, Novi Sad, Zemun, Smederevo, Banatska Palanka, and Tekija, in the period 2016-2022 (overall summary for all sampling locations combined). While metals such as Cd, Pb, Ni, Zn, Cu, Cr, and metalloid As are part of Serbia's official monitoring, the emphasis was placed on the frequency of detection of additional pollutants and hazardous substances. Results revealed that industrial chemicals, including para-tert-octylphenol, PCB 194, and bisphenol A, along with pesticides such as atrazine, terbuthylazine, metolachlor, and isoproturon, were detected above the limit of quantification in over 30% of the samples analyzed. Currently, there is insufficient data on pesticide usage and a lack of a comprehensive database detailing the quantities of chemicals applied in agriculture [15]. To better understand trends in pollutant concentrations and potential sources, a detailed analysis based on sampling locations is necessary, along with a spatial comparison of pollutant distributions across Serbia. The investigation of correlations between seasonal water level fluctuations and pollution concentration parameters is recommended to further elucidate the dynamics of these pollutants and their sources in the Danube River Basin.

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