



UNIVERSITY OF NOVI SAD  
Technical faculty "Mihajlo Pupin"  
Zrenjanin, Republic of Serbia

In cooperation with partners

*Industrial Engineering  
and  
Environmental Protection*

**I I Z S**  
conference

PROCEEDINGS

**XI International Conference –  
Industrial Engineering And Environmental  
Protection (IIZS 2021)**

Zrenjanin, 7<sup>th</sup>-8<sup>th</sup> October 2021.



University of Novi Sad  
Technical faculty “Mihajlo Pupin”  
Zrenjanin, Republic of Serbia




# **XI International Conference - Industrial Engineering and Environmental Protection (IIZS 2021)**

Proceedings

Zrenjanin, 7 – 8<sup>th</sup>, October 2021.



IN COOPERATION WITH PARTNERS:

 <p>UP T Universitatea Politehnica Timișoara</p>	<p>UNIVERSITY POLITEHNICA TIMISOARA, FACULTY OF ENGINEERING, HUNEDOARA, ROMANIA</p>	
	<p>UNIVERSITY «St. KLIMENT OHRIDSKI», TECHNICAL FACULTY, BITOLA, MACEDONIA</p>	
	<p>„AUREL VLAICU” UNIVERSITY OF ARAD, FACULTY OF ENGINEERING, ARAD, ROMANIA</p>	
	<p>UNIVERSITY OF EAST SARAJEVO, FACULTY OF MECHANICAL ENGINEERING EAST SARAJEVO, REPUBLIC OF SRPSKA, B&amp;H</p>	
	<p>UNIVERSITY OF GIRE SUN, FACULTY OF ENGINEERING, GIRE SUN, TURKEY</p>	

# Proceedings of the XI International Conference - Industrial Engineering and Environmental Protection (IIZS 2021)

## Conference organizer:

Technical faculty "Mihajlo Pupin", Zrenjanin, University of Novi Sad, Republic of Serbia

## Reviewers:

PhD Snežana Filip, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Slavica Prvulović, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Ljiljana Radovanović, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Bogdana Vujić, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Eleonora Desnica, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Vladimir Šinik, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Jasmina Pekez, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Višnja Mihajlović, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Zoran Čepić, Faculty of Technical Sciences. Novi Sad, Serbia  
PhD Nina Đapić, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Jasna Tolmač, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Dejan Đorđević, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Mihalj Bakator, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Edit Terek Stojanović, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Milija Krajišnik, Mechanical Faculty, East Sarajevo, Bosnia and Herzegovina

## Publisher:

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

## For publisher:

PhD Dragica Radosav, Dean of Technical faculty "Mihajlo Pupin", Zrenjanin

## Technical treatment:

PhD Mića Đurđev, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia  
PhD Jasna Tolmač, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia  
MSc Borivoj Novaković, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia

---

Organization of this Conference is supported by the Ministry of Education, Science and Technological Development, Republic of Serbia

---

## CIP Classification:

CIP - Каталогизacija u publikaciji  
Biblioteka Matice srpske, Novi Sad

62:005.3(082)(0.034.4)

502/504(082)(0.034.4)

## **INTERNATIONAL Conference Industrial Engineering and Environmental Protection (11 ; 2021 ; Zrenjanin)**

Proceedings [Elektronski izvor] / XI International Conference Industrial Engineering and Environmental Protection (IIZS 2021), Zrenjanin, 7-8th October 2021. - Zrenjanin : Technical Faculty "Mihajlo Pupin", 2021. - 1 elektronski optički disk (CD-ROM) ; 12 cm

Nasl. sa naslovnog ekrana. - Str. 7: Introduction / Snežana Filip. - Bibliografija uz svaki rad.

ISBN 978-86-7672-348-5

а) Индустрijско инжењерство - Зборници б) Животна средина - Заштита - Зборници

COBISS.SR-ID 48776201

## **SCIENTIFIC COMMITTEE - TECHNICAL FACULTY „MIHAJLO PUPIN“**

PhD Snezana Filip, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Slavica Prvulovic, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Ljiljana Radovanovic, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Bogdana Vujic, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Eleonora Desnica, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Vladimir Sinik, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Jasmina Pekez, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia  
PhD Visnja Mihajlovic, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

## **INTERNATIONAL SCIENTIFIC COMMITTEE**

PhD James G. Speight, CD&W Inc., Laramie, Wyoming, USA  
PhD Hosam E.A.F. Bayoumi Hamuda, Obuda Univerzity, Budapest, Hungary  
PhD Svetlana Lilkova, University of Architecture, Civil Engineering and Geodesy (UACEG), Faculty of Hydraulic Engineering, Sofia, Bulgaria  
PhD Dimitar G. Petrov, Technical University Sofia, branch Plovdiv, Bulgaria  
PhD Valentina Emilia Balas, „Aurel Vlaicu" University of Arad, Faculty of Engineering, Arad, Romania  
PhD Imre Kiss, University Politehnica Timisoara, Faculty of engineering, Hunedoara, Romania  
PhD Francisc Popescu, University Politehnica Timisoara, Timisoara, Romania  
PhD Mukrimin Sevkett Guney, University of Giresun, Faculty of Engineering, Giresun, Turkey  
PhD Mustafa Serkan Soylu, University of Giresun, Faculty of Engineering, Giresun, Turkey  
PhD Yalcın Tepe, University of Giresun, Faculty of Engineering, Giresun, Turkey  
PhD Mustafa Tiirkmen, University of Giresun, Faculty of Engineering, Giresun, Turkey  
PhD Aysun Turkmen, University of Giresun, Faculty of Engineering, Giresun, Turkey  
PhD Muharrem Hilmi Aksoy, Selcuk University, Engineering Faculty, Konya, Turkey  
PhD Alexander Salnikov, Ukhta State Technical University (USTU), Ukhta, Republic of Komi, Russia  
PhD Hrvoje Glavas, Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, Croatia  
PhD Tomislav Barie, Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, Croatia  
PhD Silva Lozancic, Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering, Osijek, Croatia  
PhD Mirko Karakasic, University of Slavonski Brod, Faculty of Mechanical Engineering Slavonski Brod, Slavonski Brod, Croatia  
PhD Vangelce Mitrevski, University «sv. Kliment Ohridski«, Technical Faculty, Bitola, Macedonia  
PhD Milija Krajsnik, University of East Sarajevo, Faculty of Mechanical Engineering, Republic of Srpska, Bosnia and Herzegovina  
PhD Mirjana Vojinovic Miloradov, professor emeritus, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia  
PhD Bratislav Blagojevic, University of Nis, Faculty of Mechanical Engineering, Nis, Serbia  
PhD Blaza Stojanovic, University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia  
PhD Dragan D. Milanovic, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia  
PhD Mijodrag Milosevic, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia  
PhD Dejan Lukic, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia  
PhD Milan Rackov, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia  
PhD Jasmina Radosavljevic, University of Nis, Faculty of Occupational Safety, Nis, Serbia  
PhD Amelija Dordevic, University of Nis, Faculty of Occupational Safety, Nis, Serbia  
PhD Snezana Dragicevic, University of Kragujevac, Faculty of Technical Sciences, Cacak, Serbia  
PhD Ivona Radovic, University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia  
PhD Mirjana Kijevcanin, University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia  
PhD Aleksandra Sretenovic, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia  
PhD Aleksandra Mihailovic, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia  
PhD Nebojsa Ralevic, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia  
PhD Maja Petrovic, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia

PhD Aleksandar Asonja, University Business Academy in Novi Sad, Faculty of Economics and Engineering Management in Novi Sad, Serbia

PhD Marina Milovanovic, University "Union - Nikola Tesla", Faculty for entrepreneurial business and real estate management, Belgrade, Serbia

PhD Jasmina Perisic, University "Union - Nikola Tesla", Faculty for entrepreneurial business and real estate management, Belgrade, Serbia

PhD Jordana Ninkov, Senior Research Associate, Institute of Field and Vegetable Crops, Novi Sad, Serbia

PhD Tamara Ivetic, Senior Research Associate, University of Novi Sad, Faculty of Sciences, Department of Physics, Novi Sad, Serbia

PhD Marko Ristic, Research Associate, Institute Mihajlo Pupin, Belgrade, Serbia

### **Organizing Committee:**

**PhD Snežana Filip, President, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia - Chairman**

PhD Ljiljana Radovanović, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

PhD Slavica Prvulović, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

PhD Eleonora Desnica, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

PhD Bogdana Vujić, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

PhD Jasmina Pekez, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

PhD Visnja Mihajlović, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

PhD Vladimir Šinik, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

PhD Zoran Čepić, Faculty of Technical Sciences, Novi Sad, Serbia

PhD Jasna Tolmač, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

PhD Mića Đurđev, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

MSc Ivan Palinkaš, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

MSc Una Marčeta, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

MSc Borivoj Novaković, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

BSc Eleonora Terečik, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

## **Word of Thanks**

We wish to thank Ministry of Education,  
Science and Technological Development, Republic of Serbia,  
for donating financial means to  
the Conference Proceedings and organization of the  
XI International Conference -  
Industrial Engineering and Environmental Protection (IIZS 2021)

# INTRODUCTION

---

Departments of Mechanical engineering and Department of Environmental protection of Technical Faculty "Mihajlo Pupin", Zrenjanin, has organized the XI International Conference Industrial Engineering and Environmental Protection – IIZS 2021.

The topics of scientific conference «IIZS 2021», 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: innovation and expansion of knowledge engineers in industry and environmental protection; support to researchers in presenting the actual results of research projects, establishing new contacts with leading national and international institutions and universities; popularization of the faculty and its leading role in our society and the immediate environment, in order to attract quality young population for studying at our faculty, cooperation with other organizations, public companies and industry; initiative for collecting ideas in solving specific practical problems; interconnection and business contacts; introducing professional and business organizations with results of scientific and technical research; presentation of scientific knowledge and exchange of experiences in the field of industrial engineering.

We would like to express our gratitude to the partners of the conference – „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; University of Giresun, Faculty of engineering, Giresun, Turkey for supporting the organization of the 11<sup>th</sup> International Conference «IIZS 2021». We are also grateful to all the authors who have contributed with their papers to the organization of the scientific meeting «IIZS 2021».

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 2021».

The IIZS Conference became a traditional meeting of researchers from all over the world, every year. We are open and thankful for all useful suggestions which could contribute that the next, XII International Conference - Industrial Engineering and Environmental Protection, become better in organizational and program sense.

Chairman of the Organizing Committee  
Asst. prof. Snežana Filip

Zrenjanin, 7 - 8<sup>th</sup> October 2021.



**Conference participants are from the following countries:**



Romania



Bosnia and Herzegovina



Hungary



North Macedonia



Bulgaria



Croatia



Turkey



Iran



Austria



Serbia



Portugal



Russian Federation

# CONTENTS

## PLENARY SESSION

SURFACE WATER QUALITY ON CERNA RIVER (Francisc Popescu, Milan Trumic, Bogdana Vujic, Nada Strbac, Adrian Eugen Cioabla, Vukosav Antonijevic, Carmen Radescu, Gavril Trif-Tordai).....	2
ENERGY RENOVATION OF SCHOOL BUILDINGS IN OSIJEK-BARANJA COUNTY (Držislav Vidaković, Silva Lozančić, Marijana Hadzima-Nyarko, Marija Krajnović) .....	6
EMOTIONAL INTELLIGENCE AND LEADERSHIP IN CONSTRUCTION MANAGEMENT (Nazi Ghamkhar, Ali Reza Afshari, Sanja Stanisavljev) .....	15
ENVIRONMENTAL FACTORS AND SPREADING OF COVID-19 VIRION (Hosam E.A.F. Bayoumi Hamuda) .....	25

## I - INDUSTRIAL ENGINEERING

### Session 1: Mechanical Engineering

NEW CONCEPT HAZELNUT UNSHELLING APPARATUS (Mukrimin S. Guney) .....	46
DYNAMIC STABILITY OF A FLUID-IMMERSED PIPE CONVEYING FLUID AND RESTING ON A DAMPED WINKLER ELASTIC FOUNDATION (Dimitar Lolov, Svetlana Lilkova-Markova) .....	49
ESTABLISHMENT OF WORKING UNITS IN THE MACHINE TOOLS OVERHAUL PRODUCTION SYSTEM (Bogdan Marić, Vlado Medaković).....	56
ESTABLISHING PULL SYSTEM IN ORDER MANUFACTURING – CASE STUDY (Bogdan Marić, Vlado Medaković).....	62
THE INFLUENCE OF CARBON FIBER ORIENTATION ANGLE ON BUCKLING PROPERTIES OF FOUR-LAYER SYMMETRIC LAMINATE UNDER BIAXIAL COMPRESSION (Dejan Jeremić, Nebojša Radić, Nikola Vučetić).....	70
NEWS IN INDUSTRIAL APPLICATION OF CATHODIC CAGE PLASMA NITRIDING (Željko Stojanović, Slavica Prvulović, Sanja Stanisavljev, Mila Kavalić) .....	78
APPLICATION OF HYBRID TECHNOLOGIES IN THE FUNCTION OF IMPROVING THE PERFORMANCE OF HOT FORGING TOOLS (Željko Stojanović, Slavica Prvulović, Sanja Stanisavljev, Mila Kavalić) .....	87
APPLICATION OF ISO – IEC 80000-6:2008 IN THE DESCRIPTION OF TECHNICAL SYSTEMS (Domagoj Pejakušić, Yvonne Liermann-Zeljak, Hrvoje Glavaš) .....	97
DETERMINATION OF NATURAL FREQUENCY AND AMPLITUDE RATIO OF A RAYLEIGH DOUBLE BEAM SYSTEM WITH A KEER MIDDLE LAYER SUBJECTED TO COMPRESSIVE AXIAL LOAD (Branislav Milenković, Danilo Karličić, Đorđe Jovanović) .....	103

MOLD CAVITY LAYOUT DESIGN (Ivan Matin, Branko Štrbac, Miloš Ranisavljev, Đorđe Vukelić, Miodrag Hadžistević) .....	112
VANADIUM IN TOOL STEELS (Zoran Karastojković, Jasmina Pekez, Nikola Bajić) .....	117
STUDY ON THE DRIVER ERGONOMIC POSITION INSIDE DIFFERENT TYPES OF VEHICLES (Alexandru Dumitru Antonie, Adrian Eugen Cioabla) .....	128
<b>Session 2: Energetics and Process Technique</b>	
THE DEVICE FOR THE PRODUCTION AND THE USAGE OF THE BIOGAS THROUGH THE ANAEROBIC FERMENTATION OF THE MIXTURE OF THE FRAGMENTED BIOMASS AND THE STABLE DUNG (Slavica Prvulović, Jasna Tolmač, Milica Josimović, Ivica Micić, Miloš Josimović) .....	130
ADVANTAGES OF BIOGAS POWER PLANTS IN ENERGY TRANSITION PANNONIAN COUNTRIES (1) - Benefits for the local community (Milan Ivanović, Hrvoje Glavaš) .....	138
ADVANTAGES OF BIOGAS POWER PLANTS IN ENERGY TRANSITION PANNONIAN COUNTRIES (2) - Benefits for the national economy (Milan Ivanović, Hrvoje Glavaš) .....	144
THE IMPACT OF VALID REGULATIONS ON ELECTROMAGNETIC FIELDS OF THE ERNESTINOVO SUBSTATION (Robert Noskov, Ivica Petrović, Hrvoje Glavaš) .....	150
STATISTICAL EVALUATION OF SOME FIVE PARAMETERS SORPTION ISOTHERMS MODELS (Vangelce Mitrevski, Cvetanka Mitrevska) .....	156
HEAT STORAGE FOR RESIDENTIAL SECTOR APPLIANCE (Milena Mančić, Miomir Raos, Milena Medenica, Milan Protić) .....	162
SONOMETRIC MEASUREMENTS IN AGRICULTURAL APPLICATIONS – CASE STUDY (Timotei Bogdan Bacos, Adrian Eugen Cioabla) .....	170
PROBLEMS RELATED TO THE ELECTRIC POWER SYSTEM OF WIND FARMS AND NEW TENDENCIES IN THEM (Vladimir Šinik, Željko Despotović, Branko Radović, Mića Đurđev, Miloš Josimović) .....	175
UNSUSTAINABLE DEVELOPMENT AND AGRICULTURE (Radovan Pejanović, Marijana Dukić-Mijatović, Jelena Ješić) .....	182
OPERATING MODELS FOR PV SYSTEMS IN EXISTING RESIDENTIAL BUILDING COMPLEXES IN VIENNA – CHALLENGES AND OPPORTUNITIES (Momir Tabakovic, Marlen Würfl, Eduardo Guerra, Miriam Gutleder) .....	186
COOLING TECHNOLOGIES OF DATA CENTERS (Stanko P. Stankov) .....	194
INFLUENCE OF PANEL LOCATION AND ORIENTATION ON EFFICIENCY OF PHOTOVOLTAIC POWER PLANT (Luka Đorđević, Jasmina Pekez, Borivoj Novaković, Mića Đurđev, Ivan Palinkaš, Dragana Milosavljev, Branko Markoski) .....	202

### **Session 3: Designing and Maintenance**

DETECTION OF INDUSTRIAL FAN MOTOR BEARING FAULTING BY IMPLEMENTATION OF VIBRODIAGNOSTIC METHODS (Borivoj Novaković, Ljiljana Radovanović, Eleonora Desnica, Luka Đorđević, Mića Đurđev)	212
CONDITION MONITORING AND DIAGNOSTICS OF SLIDING BEARINGS (Ranko Antunović, Nikola Vučetić, Eleonora Desnica, Imre Kiss)	218

### **Session 4: Oil and Gas Engineering**

RESULTS OF EXPERIMENTAL RESEARCH OF HEAT TRANSFER COEFFICIENT THROUGH THE MAIN OIL PIPELINE (Jasna Tolmac, Slavica Prvulovic, Sasa Jovanovic, Milan Markovic, Dragisa Tolmac)	226
LABORATORY TESTING, EVALUATION AND ANALYSIS OF PORTLAND CEMENT IN OIL AND GAS WELLS (Milan Marković, Saša Jovanović, Jasna Tolmač, Isidora Popov)	232

### **Session 5: Engineering Management**

SELECTION OF CONSTRUCTION SITE MANAGER IN THE COMPANY “KRAFT PORT” DOO NOVI SAD: MULTICRITERIA APPROACH (Branislav Kuzmanović, Srdana Taboroši, Jelena Rajković, Siniša Mitić, Milan Nikolić)	241
INTERNAL COMMUNICATION IN THE COMPANY “KRAFT PORT” DOO NOVI SAD (Branislav Kuzmanović, Jelena Rajković, Srdana Taboroši, Siniša Mitić, Milan Nikolić)	247
THE SOCIO-ECONOMIC ASPECTS OF THE CIRCULAR ECONOMY MODEL (Dejan Đorđević, Dragan Čočkaló, Mihalj Bakator, Ljiljana Đorđević, Srđan Bogetić)	253
IMPROVING COMPETITIVENESS THROUGH TECHNOLOGICAL AND INDUSTRIAL INNOVATION (Dragan Čočkaló, Mihalj Bakator, Dejan Đorđević, Sanja Stanisavljev, Miloš Vorkapić)	258
ACHIEVING SUSTAINABLE DEVELOPMENT THROUGH THE CONCEPT OF SOCIETY 5.0 (Mihalj Bakator, Dejan Đorđević, Dragan Čočkaló, Cariša Bešić, Dragana Milosavljev)	265
ECOLOGICAL IMPACT OF TELEWORK (Srdana Taboroši, Biljana Maljugić, Aleksandra Kovačević)	270
ANALYSIS OF OPPORTUNITIES FOR PRODUCTIVITY IMPROVEMENT OF DOMESTIC ENTERPRISES (Biljana Maljugić, Srdana Taboroši)	274
ANALYSIS OF THE APPLICATION OF INTERNATIONAL STANDARDS IN BUSINESS PRACTICE (Biljana Maljugić, Marija Matotek Andelić)	282
PRODUCTION FLOW DIAGRAM OF PLEATED BLINDS (Dijana Tadić, Maja Knežević)	290
THE COMPARATIVE ANALYSIS REGARDING THE URBAN TRANSPORT TIMISOARA – LISBON THROUGH THE FASHION OF LINEAR (Patrick Stefanescu, Luisa Izabel Dungan)	298

CONSTRUCTION CLAIM MANAGEMENT (Ali Reza Afshari, Edit Terek Stojanović, Ali Shieh Ali).....	306
SOCIAL RESPONSIBILITY AND SUSTAINABLE DEVELOPMENT (Radmila Čokorilo, Cariša Bešić, Snežana Bešić) .....	314
CONSTRUCTION SAFETY MANAGEMENT (Ali Reza Afshari, Dragica Radosav, Elaheh Tavakolian).....	319

## II – ENVIRONMENTAL ENGINEERING

### Session 6: Health and Environmental protection

TECHNOLOGICAL PROCESSES OF COMPOSTING IN A PUBLIC UTILITY COMPANY (PUC) CITY GREENERY CACAK (Dragan Nikolić, Srećko Ćurčić, Mirjana Đoković).....	328
DETERMINATION OF ADR TRANSPORT CONDITIONS APPLICABLE TO METHYL TERT- BUTYL ETHER AS A LIQUID FLAMMABLE PETROCHEMICAL (Matilda Lazić, Miodrag Kovačević) .....	334
RID CARRIAGE CONDITIONS OF FLAMMABLE LIQUID, N.O.S. (Matilda Lazić, Miodrag Kovačević, James G. Speight, Ljiljana Radovanović).....	340
MICROPLASTICS AND IMPLICATION ON HEALTH BY USING FACE MASKS DURING THE COVID – 19 PANDEMIC (Snežana Filip, Bogdana Vujić, Una Marčeta, Eleonora Terečik).....	347
IDENTIFYING METHOD OF MANAGING MEDICAL WASTE DURING THE PANDEMIC OF COVID-19 (Eleonora Terečik, Višnja Mihajlović, Una Marčeta, Marko Jovanov).....	352
POLLUTANT EMISSIONS FROM FOSSIL FUEL COMBUSTION USED FOR ACHIEVING THERMAL COMFORT IN DETACHED RESIDENTIAL BUILDINGS (Amelija Đorđević, Ana Vukadinović, Jasmina Radosavljević, Bogdana Vujić) .....	355
IMPACT OF GREEN ROOFING ON THE ENERGY PERFORMANCE OF A DETACHED PASSIVE RESIDENTIAL BUILDING WITH A TROMBE WALL (Ana Vukadinović, Jasmina Radosavljević, Amelija Đorđević).....	362
DEVELOPMENT OF HEAT LOAD PREDICTIVE MODELS IN DISTRICT HEATING SYSTEMS USING THE BOOSTING METHOD (Milan Protić, Miomir Raos, Nikola Mišić, Jasmina Radosavljević, Lidija Milošević) .....	368
ELIMINATION LEAN WASTE IN THE PRODUCTION PROCESS (Ranka Gojković, Slaviša Moljević, Bogdan Marić, Vlado Medaković) .....	375
AIR POLLUTION FROM SOLID PARTICLES, FILTRATION AND FILTERS (Milena Medenica, Miomir Raos, Milan Protić, Milena Mančić) .....	381
DECOMPOSITION OF SELECTED PHARMACEUTICAL MICROPOLLUTANTS BY NEWLY SYNTHESIZED NANOMATERIAL (Mladenka Novaković, Dragana Štrbac, Maja Petrović, Boris Obrovski, Goran Štrbac, Ivana Mihajlović) .....	389



ADSORPTION KINETICS OF 3-(4-METHYLBENZYLIDENE) CAMPHOR ON MICROPLASTICS IN WATER ( <b>Maja Vujić, Aleksandra Tubić, Vasiljević Sanja, Jelena Molnar Jazić, Tajana Simetić, Malcolm Watson, Jasmina Agbaba</b> ) .....	394
COMPARISON OF SURFACE WATER QUALITY BETWEEN CROSS-BORDER PROTECTED AREAS IN SERBIA AND CROATIA ( <b>Boris Obrovski, Mirjana Vojinović Miloradov, Maja Sremački, Mladenka Novaković, Nevena Živančev, Maja Petrović, Ivana Mihajlović</b> ).....	400
EFFECTS OF ENVIRONMENTAL POLLUTION DUE TO LAND TRANSPORT ACTIVITY ( <b>Luisa Izabel Dungan, Adrian Eugen Cioabla, Mircea Adrian Dungan, Mariana Nela Stefanut, Francisc Popescu</b> ) .....	406
WASTEWATER MANAGEMENT: A STRENGTH OR WEAKNESS OF THE REPUBLIC OF SERBIA ON THE PATH TO THE EU? ( <b>Aleksandra Sitarević, Aleksandar Sofić</b> ) .....	412
COMPOSTING OF WASTE WATER SLUDGE FROM TEXTILE INDUSTRY ( <b>Marko Rokvić, Dejan Ubavin, Maja Sremački, Milan Milotić, Zoran Čepić</b> ) .....	419
ASSESSMENT OF MUNICIPAL SOLID WASTE GENERATION IN THE MUNICIPALITIES OF AVEIRO DISTRICT USING ANOVA (ONE WAY) ANALYSIS ( <b>Nikola Karanovic</b> ) .....	423
HEALTH AND SAFETY RISKS AND CHALLENGES FOR WORKERS IN THE TONER CARTRIDGE RECYCLING PROCES ( <b>Stepan Polygalov, Marko Rokvić, Nemanja Stanisavljević, Maja Sremački, Zoran Čepić</b> ).....	429
BIOLOGICAL HAZARDS IN THE WORKING ENVIRONMENT DURING THE OPERATION OF THE ANIMAL WASTE INCINERATOR ( <b>Galina Ilinykh, Sandra Kozomora Subotin, Nemanja Stanisavljavić, Maja Sremački, Zoran Čepić</b> ) .....	434
SAFETY AND HEALTH RISKS FOR WORKERS AT THE ANIMAL WASTE INCINERATION PLANT ( <b>Sandra Kozomora Subotin, Stepan Polygalov, Nemanja Stanisavljavić, Maja Sremački, Zoran Čepić</b> ) .....	442
IDENTIFICATION AND SIGNIFICANCE OF GRAM-NEGATIVE BACTERIA IN MSW LANDFILL LEACHATE FROM VOJVODINA REGION ( <b>Katarina Antić, Zoran Čepić, Milena Stošić, Jelena Radonić</b> ) .....	450
RELATIONSHIP BETWEEN AIR QUALITY AND DISTRIBUTION OF LICHENS AS BIOINDICATORS IN SOME SERBIAN LOCATIONS ( <b>Doris Stojilkovic, Bogdana Vujic, Hosam E.A.F. Bayoumi Hamuda</b> ) .....	458
BIOINDICATION OF AIR QUALITY USING LICHEN IN ULAANBAATAR, MONGOLIA ( <b>Tsend-Ayush Erdenejargal, Enkhtuya Ochirbat, Hosam E.A.F. Bayoumi Hamuda</b> ).....	467
BIG DATA IN WATER SUPPLY AND SEWERAGE SYSTEMS ( <b>Stanko P. Stankov</b> ) .....	474

PHENOLIC PROFILE DETERMINATION OF FRUŠKA GORA POMACES FOR UTILIZATION PURPOSES

(Diandra Pintać, Ljilja Torović, Dejan Orčić, Dejana Bajić, Branko Markoski, Neda Mimica-Dukić, Marija Lesjak) .....482

STATISTICAL ANALYSIS OF DATA OBTAINED BY MEASURING AIR QUALITY AT CHILDREN'S PLAYGROUNDS IN NOVI SAD

(Nebojša M. Ralević, Jelena S. Kiurski, Ladin Gostimirović, Aleksandra Mihailović) .....486

HAZARDS AND HARMS FROM USING CHEMICAL SUBSTANCES

(Jasmina Rajić, Aleksandar Šotić, Barbara Vidaković Ristić, Dragana Paunović, Tanja Petrović) .....495

## **Session 7: Environmental Management**

GREEN HUMAN RESOURCES MANAGEMENT AND ENVIRONMENTAL PROTECTION

(Dragana Milosavljev, Edit Terek Stojanović, Mila Kavalić, Maja Gaborov, Mihalj Bakator) .....502

CIRCULAR ECONOMY PRINCIPLES IN THE HAZARDOUS WASTE PACKAGING MANAGEMENT

(Marko Rokvić, Galina Ilinykh, Nemanja Stanisavljević, Maja Sremački, Zoran Čepić) .....509

THE ROLE OF TYPE II ENVIRONMENTAL LABELS IN CIRCULAR PACKAGING

(Milana Ilić Mićunović, Tamara Novaković, Zoran Čepić, Boris Agarski, Zorica Mirosavljević) .....515

## **Session 8: Occupational Safety**

DECISION ANALYSIS AND APPLICATION OF THE DELPHI METHOD IN THE SELECTION OF EMPLOYEE EDUCATION IN THE FORMATION OF THE INVESTMENT PROJECT

(Aleksandra Kovačević) .....522

STRENGTHENING THE CAPACITIES OF OSH IN THE DEFENSE AND SECURITY TRADE UNION (SOB) IN THE REPUBLIC OF NORTH MACEDONIA

(Monika Lutovska, Vladimir Mijakovski) .....532

STATISTICAL INDICATORS FOR ACCIDENTS AT WORK IN CONSTRUCTION SECTOR

(Cvetanka Mitrevska, Elena Mitrevska, Vangelce Mitrevski) .....539

IMPROVING WORKPLACE SAFETY USING ADVANCED INDUSTRY 4.0 TECHNOLOGIES

(Marija Savković, Marica Dašić, Marko Đapan, Arso Vukićević, Ivan Mačužić, Miladin Stefanović) .....545

DEVELOPMENT OF RISK MANAGEMENT PROCESS IN INDUSTRY

(Milica Josimovic, Milos Josimovic, Slavica Prvulovic) .....553

STABLE INSTALLATIONS FOR FIRE PROTECTION ON THE FACILITY OF THE PRIMARY SCHOOL "STANČIĆ MILAN - UČA", KUMANE

(Dragana Milosavljev, Edit Terek, Borivoj Novaković, Maja Gaborov) .....558

## IDENTIFICATION AND SIGNIFICANCE OF GRAM-NEGATIVE BACTERIA IN MUNICIPAL SOLID WASTE LANDFILL LEACHATE FROM VOJVODINA REGION

Katarina Antić<sup>1</sup>, Zoran Čepić<sup>1</sup>, Milena Stošić<sup>1</sup>, Jelena Radonić<sup>1</sup>

<sup>1</sup>University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Novi Sad, Serbia

e-mail: [zorancepic@uns.ac.rs](mailto:zorancepic@uns.ac.rs)

**Abstract:** Landfill leachate is a medium affected by a considerable number of factors, both within the landfill body (landfill age, morphological composition of waste, temperature and moisture content, landfill fluid migration, waste treatment technologies before disposal, landfill body thickness, waste decomposition phases), and outside (meteorological parameters, with an emphasis on annual precipitation). Variable and almost unpredictable qualitative composition of leachate from municipal solid waste landfills, that often includes emerging substances, such as antibiotics and endocrine disruptors, as well as heavy metals, significantly affects the structure and diversity of the present microbiological communities. By implementing leachate sampling campaigns in the winter, spring and autumn in 2019 at three non-sanitary ( $L_1$ ,  $L_2$ ,  $L_3$ ) and one sanitary ( $L_4$ ) municipal solid waste landfills in the region of Vojvodina, the presence of microorganisms *Escherichia coli*, *Klebsiella pneumoniae* and *Citrobacter freundii*, Gram-negative bacteria from the family of *Enterobacteriaceae*, in the phylum *Proteobacteria*, were detected. Due to the frequent causing of urinary, extraintestinal, diarrheal and respiratory infections, meningitis, colitis, sepsis, as well as high resistance to a range of antibiotics, Gram-negative bacteria may represent a potential risk to human and animal health, under specific exposure circumstances. In addition to the use of Gram-negative bacteria *Escherichia coli*, *Klebsiella pneumoniae* and *Citrobacter freundii* as indicators of fecal contamination, the potential of the use of the mentioned bacteria as indicators of contamination of leachate with heavy metals and organic compounds, as well as the functionality and condition of municipal solid waste landfills.

**Key words:** municipal solid waste landfills, municipal solid waste landfill leachate, microbiological parameters, Gram-negative bacteria

### INTRODUCTION

#### Municipal Solid Waste Landfill Leachate

Landfill leachate is a medium affected by a considerable number of factors, both within the landfill body (landfill age, morphological composition of waste, temperature and moisture content, landfill fluid migration, waste treatment technologies before disposal, landfill body thickness, waste decomposition phases), and outside (meteorological parameters, with an emphasis on annual precipitation). The process of landfill filtrate formation includes dissolution and dispersion of solid substances in water that is percolated through the landfill body and dissolved or suspended substances formed through biological and chemical processes taking place inside the landfill body [1].

The process of generating leachate is an integral part of the water movement cycle at a landfill. The beginning of the cycle is characterized by percolating of the received atmospheric precipitation through active layers of the deposited waste. In the process, organic and inorganic substituents, heavy metals and potentially hazardous substances present in the active layers of deposited waste are dissolved, and the process of combining percolated precipitation with moisture percolated from active layers of deposited waste is realized, thus forming an optimal medium for pollutant transport. A certain part of the formed filtrate flows away from the landfill, part returns to the atmosphere through evaporation from the upper surface of the landfill body or vegetation (transpiration), while the remaining amount of formed filtrate remains in the upper layer of the landfill, whereby moisture in waste increases and conditions for the continuous production of new volumes of leachate are ensured.

It is very difficult to predict the composition of the landfill leachate due to the complex dynamics of the processes taking place in the landfill body and the impact of a large number of factors. Qualitative, as well as quantitative composition of leachate can vary over time, and the load of pollutants reaches its peak several years after waste disposal, with a subsequent decline [2,3]. The qualitative

composition of leachate is characterized by pollutants that fall into four basic groups [4,5]: *soluble organic components* (volatile fatty acids, varieties of humic and fulvic acids), *inorganic macrocomponents* (ions of calcium (Ca<sup>2+</sup>), magnesium (Mg<sup>2+</sup>), sodium (Na<sup>+</sup>), potassium (K<sup>+</sup>), ammonium (NH<sub>4</sub><sup>+</sup>), iron (Fe<sup>2+</sup>), manganese (Mn<sup>2+</sup>), chloride (Cl<sup>-</sup>), sulphate (SO<sub>4</sub><sup>2-</sup>)), *heavy metals* (ions of cadmium (Cd<sup>2+</sup>), chromium (Cr<sup>3+</sup>), copper (Cu<sup>2+</sup>), lead (Pb<sup>2+</sup>), nickel (Ni<sup>2+</sup>) and zinc (Zn<sup>2+</sup>)), *xenobiotic organic components* (hydrocarbons, phenols, chlorinated aliphatic compounds, pesticides, dioctyl phthalate).

### Microbial Structures present in Landfill Leachates

The general division of living organisms is made into three domains - *bacteria*, *archaea* and *eukaryotes* [6,7]. The basic mechanisms and processes that take place within the municipal solid waste landfill are characterized by the presence and activity of representatives of all three previously mentioned categories.

Variations in the composition of microbiological communities due to the action of a substantial number of factors within the landfill body, such as landfill age, morphological composition of waste, temperature and moisture content, landfill fluid migration, waste treatment technologies before disposal, landfill body thickness, waste decomposition phases, are known from the literature and presented in Table 1.

Municipal solid waste landfills more than 10 years old are characterized by lower acetate concentration, lower microbiological activity, as well as a smaller number of cellulolytic bacteria [8,9]. Conditions at the mentioned landfills, namely low content of hydrocarbon (6.4 ± 1.6% of dry mass) and high pH values (7.9 ± 0.35) are in favor of the survival of gram-positive bacteria from the *Bacillaceae* family, especially the genus *Bacillus*. However, the mentioned conditions are not in favor of the survival of bacteria from *Proteobacteria* and *Methanosaeta* families. Different depths of sampling disposed waste indicate significant variations in the microbiological communities present. The deeper layers of the disposed waste are characterized by lower concentrations of acetate, due to which they represent the optimal environment for the development of *Methanoculleus*. Contrary to the above, higher layers of disposed waste are characterized by substantial concentrations of acetate that are in favor of the survival of *Methanosarcin*, resulting in a greater activity related to methane production [10]. High intake of organic matter, as well as the accumulation of acetate characterizes landfills with implemented leachate recirculation treatment. These conditions are in favor of *Methanosarcin*, but not of bacteria from *Proteobacteria* and *Methanosaeta* families [10]. Low temperatures in general lead to the formation of more diverse microbiological communities [10]. *Proteobacteria* dominate landfill sites contaminated primarily with hydrocarbons, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and heavy metals [11].

**Table 1.** Complex connections of microbial structures with specific landfill features [12]

Feature		Note	Characteristic
SAMPLE AGE	Old refuse samples	Lower concentration of acetate; Lower microbial activity; Lower number of cellulolytic bacteria.	Domination of the family <i>Bacillaceae</i> .
			Domination of the genus <i>Bacillus</i> .
			Identification of extremophiles (alkaliphiles and halophiles).
			High abundance of <i>Bacillus</i> -like DNA sequences.
			<i>Proteobacteria</i> are favoured.
			Favorable conditions for <i>Methanosaeta</i> .
			Favorable conditions for hydrogenotrophic and formate-using methanogens.

	Young refuse samples	Higher concentration of acetate; Higher microbial activity; Higher number of cellulolytic bacteria.	Unfavorable conditions for gram- bacteria like <i>Proteobacteria</i> . Favorable conditions for <i>Methanosarcina</i> . Favorable conditions for acetolactic, hydrogenotrophic and formate-using methanogens.
	--	--	Significant structure changes of the methanogenic community happen shortly after waste burial.
<b>DEPTH</b>	Deeper waste layers	Lower concentration of acetate.	Favorable conditions for <i>Methanoculleus</i> .
	Upper waste layers	Higher concentration of acetate.	Favorable conditions for <i>Methanosarcina</i> . Higher methane production activity.
<b>HIGH pH</b>	Incineration ash layer in landfill	--	Dominated by <i>Bacillus</i> .
<b>ORGANIC MATTER CONCENTRATIONS</b>	High organic matter concentrations	--	High diversity of microbial communities.
<b>LEACHATE</b>	Full-scale recirculation of leachate	High input of organic matter associated with leachate recirculation; Accumulation of acetate.	Favorable conditions for <i>Methanosarcina</i> ; No detection of <i>Methanosaeta</i> . Very low abundance of <i>Proteobacteria</i> .
	Closed landfill	Stable conditions.	Favorable conditions for <i>Methanosaeta</i> ; Low abundance of <i>Methanosarcina</i> . High abundance of <i>Proteobacteria</i> , mainly <i>Gammaproteobacteria</i> .
<b>TEMPERATURE</b>	Lower Temperature	--	Higher microbial diversity.
	High Temperature	40-50 °C	Low archaeal diversity.
<b>CONTAMINATED SITE</b>	Pollutants: Hydrocarbons; PAH; PCB; Heavy metals.	--	Domination of <i>Proteobacteria</i> .
	Contamination intensity		Lowest microbial diversity and lowest enzymatic activity in areas with highest pollutant concentrations



Optimal conditions for the development and survival of Gram-negative bacteria from the family *Enterobacteriaceae*, phylum *Proteobacteria*, are the pH value of the environment between 6.6 and 7.5, as well as the temperature of 35 °C [13]. An overview of the identification of Gram-negative bacteria in municipal solid waste landfill leachate done by some other authors are shown in Table 2.

**Table 2.** Identification of Gram-negative bacteria in the MSW landfill leachate

SPECIES	LANDFILL SITE	REFERENCE
<i>Proteus mirabilis</i> ; <i>Klebsiella pneumoniae</i> ; <i>Escherichia coli</i> ; <i>Acinetobacter calcoaceticus</i> ; <i>Yersinia enterocolitica</i> ; <i>Stenotrophomonas maltophilia</i> ; <i>Citrobacter freundii</i> .	Noble Hill Sanitary Landfill at Springfield, USA	[14]
<i>Actinobacillus pleuropneumoniae</i> ; <i>Bordetella</i> sp.; <i>Escherichia coli</i> var II; <i>Brucella</i> sp.; <i>Acinetobacter baumannii</i> ; <i>Klebsiella pneumoniae</i> ; <i>Ochrobactrum anthropi</i> ; <i>Salmonella</i> spp.	San Nicolás landfill at Aguascalientes, Mexico	[15]
<i>Klebsiella pneumoniae</i> ; <i>Escherichia coli</i> ; <i>Citrobacter freundii</i> ; <i>Proteus mirabilis</i> ; <i>Vibro</i> spp.; <i>Salmonella</i> spp.	Five active landfill sites in the Ashanti Region, Ghana	[16]

## MATERIAL AND METHODS

Leachate sampling campaigns were carried out in the winter, spring and autumn of 2019, in cycles of 2 hours at each location. Sampling was carried out in accordance with instruction Q3.BP. 853 (in accordance with SRPS EN ISO 19458:2009) at three non-sanitary ( $L_1$ ,  $L_2$ ,  $L_3$ ) and one sanitary ( $L_4$ ) municipal solid waste landfill in the region of Vojvodina. At each site, 0.5 L of leachate was collected for the purpose of microbiological analyses. All samples were delivered to the laboratory and stored at a temperature of 4 °C until the sample was prepared for analysis.

Microbiological analyses were carried out at the Institute of Public Health of Vojvodina in Novi Sad, Republic of Serbia.



**Fig. 1.** Three non-sanitary,  $L_1$  (upper left),  $L_2$  (upper right),  $L_3$  (lower left) and one sanitary,  $L_4$  (lower right) MSW landfills from the region of Vojvodina on which landfill leachate sampling was conducted

## RESULTS AND DISCUSSION

The results of microbiological analyses of leachate sampled at three non-sanitary ( $L_1$ ,  $L_2$ ,  $L_3$ ) and one sanitary ( $L_4$ ) municipal solid waste landfill in the region of Vojvodina in the winter, spring and summer period are shown in Table 3.

**Table 3.** Species of identified microorganisms at four MSW landfill sites by seasons

	$L_1$	$L_2$	$L_3$	$L_4$
<b>Winter</b>	<i>Escherichia coli</i> (37°C, 44°C); <i>Klebsiella pneumoniae</i> (37°C, 44°C).	/	<i>Escherichia coli</i> (37°C, 44°C); <i>Klebsiella pneumoniae</i> (37°C, 44°C).	<i>Escherichia coli</i> (37°C, 44°C).
<b>Spring</b>	<i>Klebsiella pneumoniae</i> (37°C, 44°C).	<i>Citrobacter</i> spp. (37°C, 44°C); <i>Escherichia coli</i> (37°C, 44°C).	<i>Escherichia coli</i> (37°C, 44°C); <i>Klebsiella pneumoniae</i> (37°C, 44°C).	<i>Citrobacter freundii</i> (37°C, 44°C); <i>Klebsiella pneumoniae</i> (37°C, 44°C).
<b>Autumn</b>	<i>Escherichia coli</i> (37°C, 44°C); <i>Klebsiella oxytoca</i> (37°C, 44°C).	<i>Escherichia coli</i> (37°C, 44°C).	<i>Escherichia coli</i> (37°C, 44°C); <i>Klebsiella oxytoca</i> (37°C, 44°C).	<i>Citrobacter freundii</i> (37°C, 44°C); <i>Escherichia coli</i> (37°C, 44°C).

Frequently identified microorganisms at all four municipal solid waste landfill sites are *Escherichia coli* and *Klebsiella pneumoniae*. The presence of *Citrobacter freundii* microorganisms was identified

at the  $L_2$  landfill site in the spring season, as well as at the  $L_4$  landfill site during the spring and autumn seasons.

The detected microorganisms *Escherichia coli*, *Klebsiella pneumoniae* and *Citrobacter freundii* are Gram-negative bacteria from the family of *Enterobacteriaceae*, phylum *Proteobacteria* [17].

*Escherichia coli* is an aerobic and facultatively anaerobic bacteria that ferments lactose. It grows well in laboratory conditions, and for most serotypes the optimal temperature for reproduction is around 37°C. It is a rather resistant bacteria and it can survive in water and soil for months, with an extended period of staying on various objects. It reproduces easily and quickly in different types of food. A temperature of 60°C can kill them after 15 min [17]. *Escherichia coli* falls into the group of coliform bacteria, as it belongs to the normal human gut flora. In respect of the above, in sanitary inspections of drinking water and food they are used as indicators of fecal contamination. The mentioned bacteria can cause extraintestinal and diarrheal diseases in humans. This bacteria can be transmitted through intake of contaminated water and food and through contact with infected humans and animals [17].

*Klebsiella pneumoniae* is a facultative anaerobic bacterium that ferments lactose. The mentioned bacteria are characterized by rounded ends, they have no flagella and they are immobile, and so they are distributed individually or in pairs. Fimbriae with adherent properties and a capsule are significant virulence factors [17]. *Klebsiella pneumoniae* is a common cause of a hospital-acquired pneumonia and infections in immunocompromised patients. The nasopharynx and intestines are the centers of concentration and routes of transmission of the mentioned bacterium in humans. However, fecal contamination is the most common cause of infections caused by *Klebsiella pneumoniae* [17].

*Citrobacter freundii* is a facultatively anaerobic bacterium that does not ferment lactose. In general, most of the mentioned bacteria are characterized by the presence of several flagella for the purpose of movement, but there are also exceptions to the mentioned case. The above bacteria can be found in soil, water, sewage, food, but also in the digestive tract of animals and humans [17]. *Citrobacter freundii* is mentioned as the cause of infections of the urinary tract and respiratory organs, meningitis, sepsis, while their presence is also detected in decubitus ulcers. They are also a cause of healthcare associated infections, especially in pediatric and immunocompromised patients [17].

Based on the above, as causes of urinary, extraintestinal, diarrheal and respiratory infections, meningitis, colitis, and sepsis, *Escherichia coli*, *Klebsiella pneumoniae* and *Citrobacter freundii* may pose a significant risk to human and animal health, under certain exposure circumstances.

The presence of the mentioned Gram-negative bacteria from the phylum *Proteobacteria* can also be used as an indicator of the performance of landfill sites at which sampling was done, as well as the qualitative composition of leachate. The lower diversity of microbiological communities at landfills  $L_1$ ,  $L_2$ ,  $L_3$  and  $L_4$  indicates the prevailing conditions, which is - lower concentrations of acetate and hydrocarbons, as well as high pH value that characterize landfill sites that are more than 10 years old. Recirculation of municipal solid waste landfill leachate, as a primary treatment, is characterized by a high content of organic matter and accumulation of acetate, which are not favorable conditions for the development and survival of a range of Gram-negative bacteria. Based on the research conducted by other authors, it has been determined that due to the high concentrations of total hydrocarbons, significant microbiological enzyme activity was detected [11]. According to the above conclusions, identification of Gram-negative bacteria from the phylum *Proteobacteria* may also indicate contamination of leachate with organic pollutants, primarily hydrocarbons, polycyclic aromatic hydrocarbons, polychlorinated biphenyls and heavy metals [11].

Municipal solid waste landfills are very complex environments with variable and almost unpredictable qualitative composition of leachate, which often includes emergent substances, such as antibiotics and endocrine disruptors, as well as heavy metals, which significantly affect the structure and diversity of present microbiological communities. Therefore, the risk of developing antibiotic resistance in microorganisms is constantly increasing. The literature data according to which we are led to this doubt refers that the 50 *Escherichia coli* isolates tested were resistant to the antibiotics penicillin and erythromycin (100%), nalidixic acid (98%), cephalexin (94%), amoxicillin (86%), ampicillin (84%), ciprofloxacin (74%), tetracycline (64%), cefixime (54%) and gentamicin (36%) [18]. Most *Klebsiella pneumoniae* isolates showed an outstanding antibiotic resistance. A more favorable situation was only in the case of meropenem (1.20%), amikacin (4.79%) and piperacillin/tazobactam (10.53%) [19]. Gram-negative bacteria *Citrobacter freundii* showed antibiotic resistance to aminoglycoside

antibiotics (gentamicin, netilmicin and amikacin), fluoroquinolone antibiotics (levofloxacin, ciprofloxacin) and carbapenems (ertapenem, imipenem) and meropenem [20].

Due to the high prevalence of antibiotic resistance in Gram-negative bacteria from the family of *Enterobacteriaceae*, phylum *Proteobacteria*, displayed in numerous studies, there is an obvious need for careful monitoring of landfill leachate microbiological and physico-chemical properties. In addition, there is a necessity for the properly done exposure assessment of humans and animals to this leachate, in order to minimize and avoid possible health risk.

## CONCLUSION

The presence of microorganisms *Escherichia coli*, *Klebsiella pneumoniae* and *Citrobacter freundii*, Gram-negative bacteria from the family of *Enterobacteriaceae*, phylum *Proteobacteria* was detected after analyzing microbiological parameters of leachate sampled from three non-sanitary ( $L_1$ ,  $L_2$ ,  $L_3$ ) and one sanitary ( $L_4$ ) municipal solid waste landfill in the region of Vojvodina in the winter, spring and autumn periods. Frequently detected Gram-negative bacteria at all four municipal solid waste landfills are *Escherichia coli* and *Klebsiella pneumoniae*. The presence of *Citrobacter freundii* bacteria was detected at the  $L_2$  landfill site during the spring season and at the  $L_4$  landfill site during the spring and autumn seasons.

The presence of the mentioned Gram-negative bacteria of the *Proteobacteria* phylum can also be used as an indicator of the performance of landfill sites at which sampling was done, such as landfill age, morphological composition of waste, landfill body thickness, waste decomposition phases, as well as the qualitative composition of leachate. The lower diversity of microbiological communities at landfills  $L_1$ ,  $L_2$ ,  $L_3$  and  $L_4$  indicates the prevailing conditions, i.e. lower concentrations of acetate and hydrocarbons, as well as high pH values, characteristic for landfill sites that are more than 10 years old. Recirculation of municipal solid waste landfill leachate, as a primary treatment, is characterized by a high content of organic matter and accumulation of acetate, which are not favorable conditions for the development and survival of a range of Gram-negative bacteria. Identification of Gram-negative bacteria of the *Proteobacteria* phylum also indicates contamination of leachate with organic pollutants, primarily hydrocarbons, polycyclic aromatic hydrocarbons, polychlorinated biphenyls and heavy metals.

Gram-negative bacteria *Escherichia coli*, *Klebsiella pneumoniae* and *Citrobacter freundii* have been identified as common causes of urinary, extraintestinal, diarrheal and respiratory infections, meningitis, hemorrhagic and entero-hemorrhagic colitis, sepsis. Due to the data presented in the literature related to the antibiotics resistance of Gram-negative bacteria, it is necessary to pay attention to this phenomenon in the case of the analyzed leachates from the Vojvodina region.

By optimizing and enhancing the analyses of microbiological parameters of leachate, besides the use in the form of fecal contamination indicators, Gram-negative bacteria could also become potentially reliable indicators of leachate contamination with heavy metals and organic compounds, as well as indicators of functionality and condition of municipal solid waste landfills.

## ACKNOWLEDGMENT

This paper has been supported by the Ministry of Education, Science and Technological Development through the project no. 451-03-68/2020-14/200156: "Innovative scientific and artistic research from the FTS (activity) domain".

## REFERENCES

- [1] Brennan, R.B., Healy, M.G., Morrison, L., Hynes, S., Norton, D., Clifford, E., Management of landfill leachate: The legacy of European Union Directives, *Waste Management*, Vol. 55, pp. 355-363, 2015.
- [2] Bagchi, A.: *Design of Landfills and Integrated Solid Waste Management*, John Wiley & Sons, Inc., New Jersey, 2004.
- [3] Christensen, T.H., Cossu, R., Stegmann, R., *Landfilling of Waste: Leachate*, Elsevier Science Publishers Ltd., London, 1992.

- [4] Christensen, J.B., Jensen, D.L., Filip, Z., Gron, C., Christensen, T.H., Characterization of the dissolved organic carbon in landfill polluted groundwater, *Water Research*, Vol. 32 (1), pp. 125-135, 1998.
- [5] Kjeldsen, P., Barlaz, M.A., Rooker, A.P., Baun, A., Ledin, A., Christensen, T.H., Present and long-term composition of MSW landfill leachate: A Review, *Critical Review in Environmental Science and Technology*, Vol. 32 (4), pp. 297-336, 2002.
- [6] Maier, R.M., Pepper, I.L., Gerba, C.P.: *Environmental Microbiology*, Academic Press, San Diego and London, 2000.
- [7] Parte, A. C., LPSN—list of prokaryotic names with standing in nomenclature, *Nucleic Acids Research*, Vol. 42, pp. 613-616, 2014.
- [8] Huang, L.-N., Zhou, H., Chen, Y.-Q., Luo, S., Lan, C.-Y., Qu, L.H., Diversity and structure of the archaeal community in the leachate of a full-scale recirculating landfill as examined by direct 16S rRNA gene sequence retrieval, *FEMS Microbiology Letters*, Vol. 214, pp. 235-240, 2002.
- [9] Wei, L., Zhou, Q., Tao, H., Removal of Organic Matter from Landfill Leachate by Advanced Oxidation Processes: A Review, *International Journal of Chemical Engineering*, Vol. 2010, pp. 1-11, 2010.
- [10] Krishnamurthi, S., Chakrabarti, T., Diversity of Bacteria and Archaea from a landfill in Chandigarh, India as revealed by culture-dependent and culture-independent molecular approaches, *Systematic and Applied Microbiology*, Vol. 36, pp. 56-68, 2013.
- [11] Pérez-Leblic, M.I., Turmero, A., Hernández, M., Hernández, A.J., Pastor, J., Ball, A.S., Rodríguez, J., Arias, M.E., Influence of xenobiotic contaminants on landfill soil microbial activity and diversity, *Journal of Environmental Management*, Vol. 95, pp. 285-290, 2012.
- [12] Buchroithner, D., *Microbiology of Landfill Sites: Review of the present State of Knowledge with particular Focus on the Carbon Cycle*, Master thesis, University of Natural Resources and Life Sciences, Vienna, 2015.
- [13] Cardinali-Rezende, J., Debarry, R.B., Colturato, L.F.D.B., Carneiro, E.V., Chartone-Souza, E., Nascimento, M.A., Molecular identification and dynamics of microbial communities in reactor treating organic household waste, *Applied Microbiology and Biotechnology*, Vol. 84, pp. 777-789, 2009.
- [14] Collins, H.C., Kennedy, A.D., The microbiological hazards of municipal and clinical wastes: A review, *Journal of Applied Bacteriology*, Vol. 73, pp. 1-6, 1992.
- [15] Flores-Tena, J.F., Guerrero-Barrera, L.A., Avelar-González, J.F., Ramírez-López, M.E., Ma. Martínez-Saldaña, C., Pathogenic and opportunistic Gram-negative bacteria in soil, leachate and air in San Nicolás landfill at Aguascalientes, Mexico, *Revista Latinoamericana de Microbiología*, Vol. 49 (1-2), pp. 25-30, 2007.
- [16] Borquaye, S.L., Ekuadzi, E., Darko, G., Ahor, S.H., Twumwah Nsiah, S., Asi Lartey, J., Mutala, H.-A., Etsiapa Boamah, V., Woode, E., Occurrence of Antibiotics and Antibiotic-Resistant Bacteria in Landfill Sites in Kumasi, Ghana, *Journal of Chemistry*, Vol. 2019, pp. 1-10, 2019.
- [17] Wanger, A., Chavez, V., Huang, P.S.R., Wahed, A., Actor, K.J., Dasgupta, A.: *Microbiology and Molecular Diagnosis in Pathology*, Elsevier Science Publishing Co. Inc., USA, 2017.
- [18] Gregova, G., Kmet, V., Antibiotic resistance and virulence of *Escherichia coli* strains isolated from animal rendering plant, *Scientific Reports*, Vol. 10, pp. 1-7, 2020.
- [19] Navnon-Venezia, S., Kondratyeva, K., Carattoli, A., *Klebsiella pneumoniae*: a major worldwide source and shuttle for antibiotic resistance, *FEMS Microbiology Reviews*, Vol. 41(3), pp. 252-275, 2017.
- [20] Liu, L., Chen, D., Liu, L., Lan, R., Hao, S., Jin, W., Sun, H., Wang, Y., Liang, Y., Xu, J., Genetic Diversity, Multidrug Resistance, and Virulence of *Citrobacter freundii* From Diarrheal Patients and Healthy Individuals, *Frontiers in Cellular and Infection Microbiology*, Vol. 8, pp. 1-10, 2018.