



THE ACADEMY OF APPLIED  
TECHNICAL STUDIES  
BELGRADE



INTERNATIONAL SCIENTIFIC  
AND PROFESSIONAL CONFERENCE  
**POLITEHNIKA 2023**

# CONFERENCE PROCEEDINGS

Belgrade, 15<sup>th</sup> December 2023



INTERNATIONAL SCIENTIFIC  
AND PROFESSIONAL CONFERENCE  
**POLITEHNIKA 2023**

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**PUBLISHER**

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

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The Academy of Applied Technical Studies Belgrade, Organizing Committee

**DESIGN OF THE CONFERENCE LOGO**

Dušan Borović

**PRINT**

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

**THE CIRCULATION**

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**ENVIRONMENT AND  
SUSTAINABLE DEVELOPMENT**

**OCCUPATIONAL HEALTH  
AND SAFETY AND FIRE SAFETY**

**SMART MANAGEMENT SYSTEMS**

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## FOREWORD

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

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

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

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

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

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

Belgrade, December 2023  
EDITORS



## ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

### INVITED PAPERS

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

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

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

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

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

*Biodegradable polyesters – from ecology to medicine*

## DESIGN

### INVITED PAPER

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

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

## MECHANICAL ENGINEERING

### INVITED PAPERS

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

*Energy savings and CO<sub>2</sub> emission reduction potential through the existing building renovation*

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

*Analysis of remediation of horizontal cylindrical tank for oil storage*

## ECOTURISAM AND RURAL DEVELOPMENT

### INVITED LECTURES

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

*Challenges of sustainable tourism: Example of Croatia*

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

*Selective forms of tourism and sustainable development of rural tourist destinations*

### INVITED PAPERS

**Radomir Stojanović, PhD, Western Serbia Academy of Applied Studies**

*Education as a pillar of sustainable agritourism in Serbia*

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

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

**Vladimir Živanović, Nevena Majstorović, Zlatibor Tourism Organization, Zlatibor**

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

## MECHATRONICS

### INVITED PAPER

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

*Towards a theory of digital twins: fundamental definition*

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# **ENVIRONMENT AND SUSTAINABLE DEVELOPMENT**







## REMOVAL OF ORGANIC AND INORGANIC POLLUTANTS FROM AQUEOUS SOLUTIONS USING STARCH-DIATOMACEOUS EARTH ADSORBENT

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**Abstract:** *Organic and inorganic pollutants, accumulated in the environment, could pose a potential danger to living organisms. Some of these pollutants negatively affect the physiological activities of living organisms, and in certain concentrations, they can be lethal to biotic communities. In addition to the natural sources of emission of these substances in the environment, a large number of anthropogenic activities contribute to a sudden increase in their concentration. The development of new and improving existing ecologically sustainable techniques to prevent or reduce their outflow and retention in the environment is more necessary than ever. Therefore, the focus of this work will be examining the efficiency of environmentally friendly adsorbent based on modified starch and diatomaceous earth for the removal of selected organic and inorganic pollutants from aqueous solutions. The influence of the chemical modification of starch, followed by the addition of diatomaceous earth, on its structural, morphological, and adsorption properties, will be examined. The possibility of using starch-diatomaceous earth adsorbent for the removal of brilliant green dye, pharmaceutical compounds, and lead ions from aqueous solutions will be evaluated through the adsorption efficiency under the given conditions.*

**Keywords:** Adsorption, Potato Starch, Brilliant Green, Pharmaceutical Compounds, Pb<sup>2+</sup> ions.

### 1. INTRODUCTION

Aware that the need for water is increasing, both due to the increase in the world's population and the increased exploitation of water resources, we see that providing sufficient amounts of water is becoming an increasingly demanding challenge [1]. Water surfaces are mostly polluted by anthropogenic activities, through industrial wastewater and municipal wastewater that are discharged directly into rivers, oceans, and other water bodies. These effluents contain different types of organic and inorganic pollutants. Contaminated surface and groundwater can be highly toxic if they enter the food chain for humans and animals [2]. Synthetic organic dyes are considered persistent bioaccumulative toxic substances. Their toxic effects include disruption of the ecological balance and carcinogenicity. They are widely used in the textile industry, as well as in the production of leather, cosmetics, paper, plastic, etc. Depending on the parent dye, its degradation can produce transformation products that can be more toxic than the original compound, or less toxic by-products can be formed instead [3]. Pharmaceuticals and their metabolites although mostly present in residual

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amounts in discharged water may have detrimental effects on living organisms and human health. Pharmaceuticals are developed to be biologically active and persistent to maintain their therapeutic activity in humans and animals. In this sense, the physicochemical properties of pharmaceutical products, such as high polarity, volatility, high lipophilicity, and persistence, can affect their removal efficiency during wastewater treatment [4]. Heavy metals enter wastewater through natural and anthropogenic sources. The former includes soil erosion, volcanic activities, and weathering of rocks and minerals, whereas the latter comprises mineral processing, fuel combustion, street run-offs, landfills, agricultural activities, and industrial activities (mining, printed board manufacturing, metal finishing and plating, semiconductor manufacturing, etc). Due to the high stability, solubility, and migration activity of heavy metals in aqueous media, untreated or inadequately treated metal-contaminated wastewater effluents cause a variety of health and environmental impacts [5,6]. The method for removing these pollutants from wastewater must meet the following conditions: a high percentage of removal, low operating costs, and a relatively fast process, without the creation of side products. As such, adsorption is distinguished, with the use of adsorbents that are available in nature in large quantities.

In this paper, the possibility of using modified starch for the removal of organic dye (brilliant green), pharmaceutical compounds (erythromycin and clopidogrel), and heavy metal ions (lead) was investigated. The starch was first chemically modified with melamine, a nitrogen-rich compound, and then in the second part of the modification, diatomaceous earth was added to investigate its effect on the adsorption properties of the modified starch.

## 2. EXPERIMENTAL PART

### 2.1 Materials

The following chemicals were used: potato starch (SuperLab, Serbia), melamine (2,4,6-triamino-1,3,5-triazine; 99 %, Fisher Scientific), diatomaceous earth (SiO<sub>2</sub> 95%, Sigma-Aldrich), brilliant green dye (90%, Sigma-Aldrich), pharmaceutical compounds (erythromycin and clopidogrel), Pb<sup>2+</sup> ions (solution of Pb(NO<sub>3</sub>)<sub>2</sub>).

In all modified samples, the base material is starch that has been chemically modified. The modification was carried out in two steps. In the first stage of modification, gelatinized starch was mixed with melamine at a temperature of 80 °C, while in the second stage of modification, amino-modified starch was mixed with diatomaceous earth at 40 °C. The materials thus obtained were dried in an oven at 50°C overnight and finally ground into powder.

Label of materials: S – native starch, de – diatomaceous earth, SM – starch modified with melamine, Sde – starch modified with diatomaceous earth, SMde – starch modified with melamine and diatomaceous earth.

### 2.2 Methods

The FTIR technique (Nicolet iS10, Thermo Scientific) was used to examine the type of functional groups on the surface of the adsorbent, while the SEM (FE-SEM, TESCAN Mira3 KSMU) was used to examine the morphological characteristics.

The investigation of pollutant adsorption by modified starch was performed in the batch mixing system, at 150 rpm, at room temperature. Adsorption of dye (brilliant green, BG) and heavy metal ions (Pb<sup>2+</sup>) was investigated from individual aqueous solutions, and the measured initial pH value of both solutions was around 5. The adsorption experiments were conducted for 180 min, with a constant dose of adsorbent (0.05 g), initial concentration (10 mg dm<sup>-3</sup>), and the volume of the solution (25 mL). The BG dye concentration in the solution was analyzed using a UV-VIS spectrophotometer for the visible range at 630 nm, while the concentration of Pb<sup>2+</sup> ions in an aqueous solution was determined using atomic absorption spectroscopy at 283 nm. Adsorption of pharmaceutical compounds (erythromycin and clopidogrel) was investigated at constant adsorbent dosage (0.05 g),

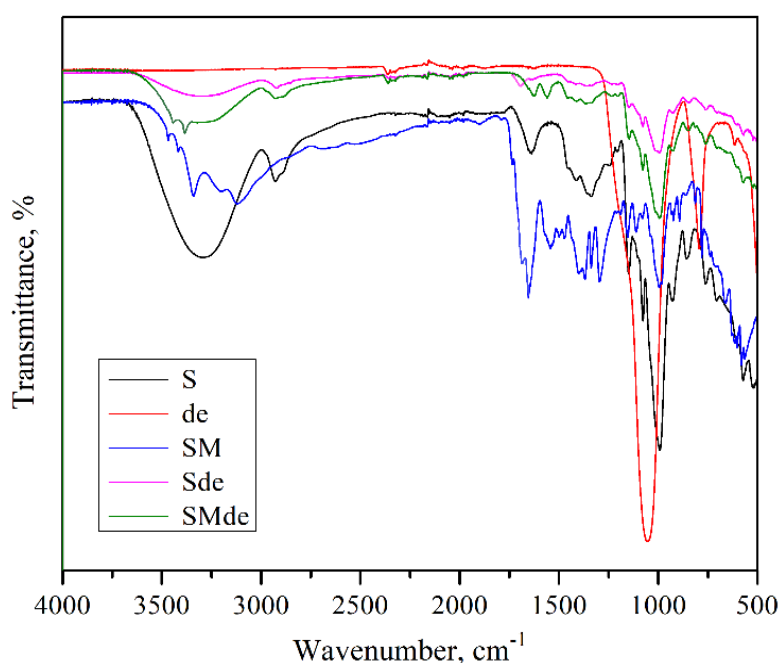
initial concentration ( $500 \text{ mg dm}^{-3}$ ), and solution volume (25 mL) for 180 min. The separation of pharmaceuticals was conducted using a Dionex UltiMate 3000® LC system (Thermo Scientific, USA). For detection and quantification of pharmaceuticals LTQ XL (Thermo Scientific, USA) mass spectrometer was used with electrospray ion source and linear ion trap mass analyzer. The removal efficiency (%) of selected pollutants from aqueous solutions, R, is calculated according to the equation (1):

$$\%R = \left( \frac{C_0 - C_t}{C_0} \right) \cdot 100 \quad (1)$$

where  $C_0$  and  $C_t$  ( $\text{mg dm}^{-3}$ ) are the concentration of pollutant at the initial time and after time  $t$  (min), respectively.

### 3. RESULTS AND DISCUSSION

FTIR is an effective technique to determine and characterize functional groups present in the material. The FTIR spectra of investigated adsorbents are shown in Figure 1., while the wavenumbers of characteristic bands in FTIR spectra are summarized in Table 1.



**Figure 1.** FTIR spectra of adsorbents

Source: original author's

By comparing the FTIR spectra, the presence of additional peaks on the FTIR spectra of modified materials was determined [7-10], which confirmed the successful synthesis of new starch-based adsorbents.

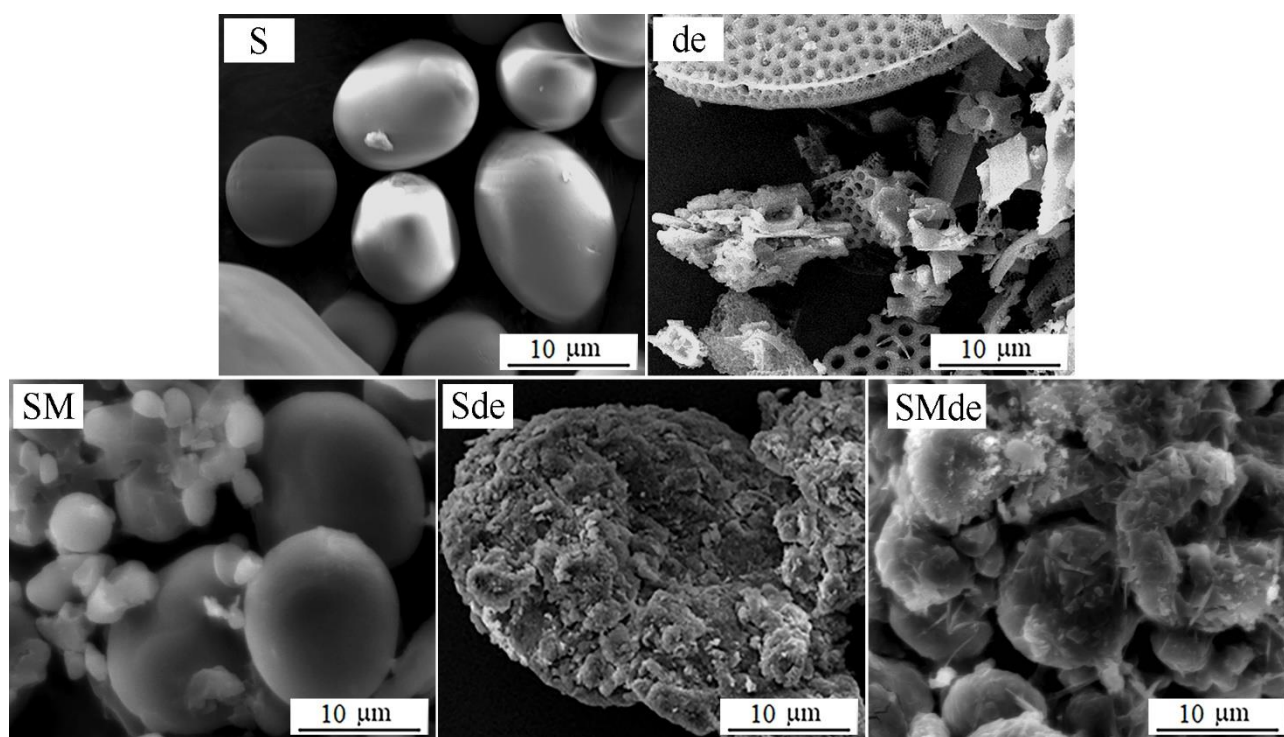
**Table 1.** FTIR wavenumber ( $\text{cm}^{-1}$ ) of adsorbents

Source: original author's

Wavenumber ( $\text{cm}^{-1}$ )	Adsorbent				
	S	de	SM	Sde	SMde
–OH stretching [7]	3335	-	3340	3335	3335
–CH <sub>2</sub> stretching [7]	2926	-	2926	2928	2926
–OH first overtone [8]	1643	-	1627	1619	1617
–C=O stretching [7]	-	-	1710	-	1714
–C–O stretching [7]	998	-	992	998	997
–NH– stretching [9]	-	-	3418	-	3412
–NH <sub>2</sub> stretching [9]	-	-	3469	-	3458

-C <sub>3</sub> H <sub>3</sub> N <sub>3</sub> ring stretching [9]	-	-	1552	-	1550
-Si-O stretching [10]	-	1072	-	1072	1075
-O-Si-O stretching [10]	-	814	-	816	816
-Si-O-Si stretching [10]	-	705	-	705	706

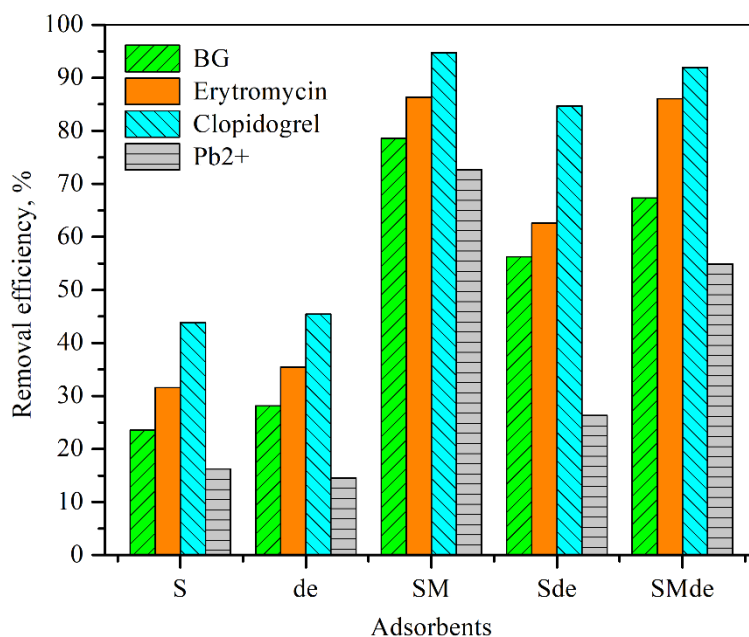
Through the micrographs obtained by SEM, it was possible to evaluate the morphological changes in modified starch granules. SEM micrographs of adsorbents are shown in Figure 2. The surface of unmodified potato starch granules is smooth, without pores and cracks, and spherical to oval in shape. SEM micrograph of diatomaceous earth (de) reveals a variety of rigid shapes and macropores, i.e. open cavities, which may be responsible for its adsorption properties. It can be noted that after the modification, there was no complete disruption of the starch granule structure (SM/Sde/SMde) compared to natural starch (S). In the case of starch modification with melamine (SM and SMde), particle agglomeration and coating of particles with melamine occur to the greatest extent. For starch modification with melamine and diatomaceous earth (SMde), it is observed that the surface of the starch granules is rougher, with ridges originating from diatomaceous earth. The starch modification with diatomaceous earth (Sde) resulted in the adhesion of diatomaceous earth to the starch surface, with the surface of the granules becoming rough with bumps and holes.



**Figure 2.** SEM micrographs of adsorbents

Source: original author's

The results of testing the adsorption properties of adsorbents based on modified starch are shown graphically in Figure 3. The results of the comparative analysis show that all examined materials show higher efficiency in removing organic pollutants compared to metal ions. The material SM, i.e. starch modified only with melamine, showed the highest efficiency in the removal of all selected pollutants. This means that the addition of diatomaceous earth after starch modification with melamine (SMde) has no effect on removal efficiency. On the other hand, the adsorbent obtained by modification of native starch with diatomaceous earth (Sde) showed better adsorption efficiency compared to the starting materials, i.e., native starch (S) and diatomaceous earth (de). The results of the adsorption experiments confirmed that the applied modification influenced the surface and morphological properties, contributing to the increase in the efficiency of modified starches to remove organic pollutants and metal ions from water.



**Figure 3.** Adsorption efficiency of examined adsorbents toward BG dye, pharmaceuticals (erythromycin and clopidogrel) and Pb<sup>2+</sup> ions  
**Source:** original author's

#### 4. CONCLUSION

In this study, the possibility of using adsorbents based on natural material, starch, for the removal of brilliant green dye, pharmaceutical compounds (erythromycin and clopidogrel), and Pb<sup>2+</sup> ions was examined. The results of FTIR and SEM analysis showed the success of the modification process and the presence of melamine and diatomaceous earth in the structure of the new adsorbents, as compounds with which the modification was performed. Higher removal percentages were obtained for organic pollutants, especially pharmaceutical compounds, compared to metal ions. The removal efficiency of the clopidogrel drug was 95.7% for the adsorbent based on modified starch with melamine and 91.6% for modified starch with melamine and diatomaceous earth. It was shown that diatomaceous earth has no effect on the adsorption properties of the material after modification with melamine, which may be a consequence of coating the pores in the diatomaceous earth structure with melamine. As the tested adsorbents, especially the material based on modified starch with melamine, proved to be promising for the removal of organic pollutants from aqueous solutions, it is necessary to conduct more extensive tests of the adsorption properties of these materials with a special focus on the removal of pharmaceutical pollutants from wastewater.

*This research was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03-47/2023-01/200135 and 451-03-47/2023-01/200287).*

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CIP - Каталогизација у публикацији  
Народна библиотека Србије, Београд

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

INTERNATIONAL Scientific and Professional Conference Politehnika (2023 ; Beograd)

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

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

ISBN 978-86-7498-110-8

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

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ISBN-978-86-7498-110-8