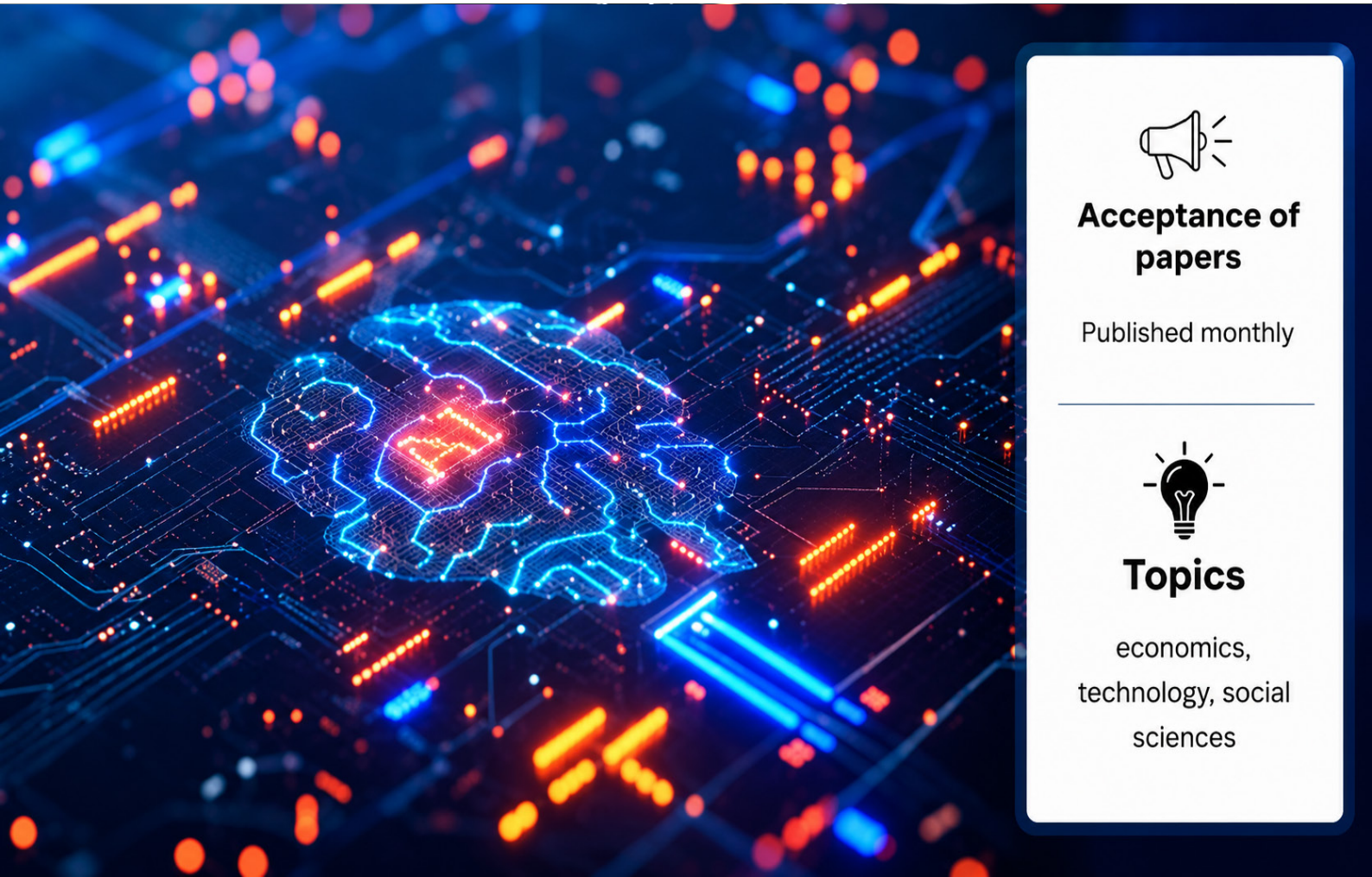
TASHKENT STATE UNIVERSITY OF ECONOMICS

International journal of topics

INNOVATION SCIENCE AND TECHNOLOGY

ISSUE 9, PART I / SEPTEMBER 2026

Acceptance of papers



Acceptance of papers

Published monthly

Topics

economics, technology, social sciences

INNOVATION SCIENCE AND TECHNOLOGY

Google Scholar

Digital Object Identifier

RePEc RESEARCH PAPERS IN ECONOMICS

ISSN 3060-5229

Electronic publication, Issue 9.
Approved for publication on September, 2026.

THE SCIENTIFIC-POPULAR ELECTRONIC JOURNAL **"INNOVATION SCIENCE AND TECHNOLOGY"** HAS BEEN REGISTERED UNDER THE NUMBER **C-5669633** BY THE AGENCY FOR INFORMATION AND MASS COMMUNICATIONS (AOKA) OF THE REPUBLIC OF UZBEKISTAN, EFFECTIVE FROM OCTOBER 9, 2024.

CONTACTS

Phone: **+998 50 737 87 88**

Website: https://ist-journal.uz

Email: innovationist2025@gmail.com

The scientific electronic journal “Innovation Science and Technology” has been included in the list of scientific publications recommended for the publication of main scientific results of dissertations for the award of PhD and DSc degrees in economics and technical sciences, in accordance with the Resolution No. 370 of the Presidium of the Higher Attestation Commission of the Republic of Uzbekistan, dated May 8, 2025.

Editorial board:

CONTENTS

CONTENTS

UO‘K (УДК, UDC) 697.1:621.577:620.9

ANALYSIS OF THERMAL AND ELECTRICAL PARAMETERS OF A PHOTOVOLTAIC-THERMAL ELECTROBIOMEMBRANE REACTOR IN WASTEWATER TREATMENT FOR MICROPOLLUTANT REMOVAL

Sevara U. Mirzayorova
Associate Professor, Department of Energy Engineering, Karshi State Technical University, Karshi, Uzbekistan
E-mail: mirzayorovasevara@gmail.com
ORCID ID: https://orcid.org/0000-0002-4563-9137
Science ID: FQD-0326-0043

ABSTRACT. This article investigates the optimization of the electrical and thermal parameters of an electrobiomembrane (EBM) reactor integrated with a hybrid photovoltaic-thermal (PV/T) system to enhance wastewater treatment efficiency in removing various micropollutants and reduce energy consumption. During the study, electricity generated by the solar panels was used to create an external electric field in the reactor, while the captured thermal energy was utilized to maintain the wastewater temperature at an optimal level. Experimental and mathematical modeling results indicated that increasing the temperature from 25 °C to 35 °C enhanced biomembrane activity and achieved a micropollutant degradation rate of up to 92.4%. Concurrently, maintaining the electric field current density within the optimal range of 5–15 A/m² reduced membrane biofouling by 38%. The thermal and electrical exergy efficiencies of the PV/T system were analyzed, resulting in a 28.5% reduction in the total energy budget of the hybrid reactor. The findings establish a scientific and technical foundation for implementing energy-efficient and environmentally safe technologies using renewable energy sources at wastewater treatment facilities.

Keywords: wastewater, micropollutants, photovoltaic-thermal system (PV/T), electrobiomembrane reactor, parameter optimization, biofouling, current density, exergy efficiency, thermal mode effect, renewable energy.

Annotatsiya. Ushbu maqolada oqova suvlarni turli mikro-ifloslantiruvchilardan tozalash samaradorligini oshirish va energiya sarfini kamaytirish maqsadida fotovoltaik-termik (PV/T) gibrid tizimi bilan integratsiyalashgan elektrobiomembrana reaktorining (EBM) elektr va issiqlik parametrlarini maqbullashtirish masalasi tadqiq etilgan. Tadqiqot davomida quyosh panellaridan olinadigan elektr energiyasi reaktordagi tashqi elektr maydonini shakllantirishga, hosil bo‘lgan issiqlik energiyasi esa oqova suv haroratini optimal darajada ushlab turishga yo‘naltirildi. Eksperimental va matematik modellashtirish natijalari shuni ko‘rsatdiki, haroratning 25 °C dan 35 °C gacha oshishi biomembrana faolligini oshirib, mikro-ifloslantiruvchilarning destruksiya darajasini 92,4% ga yetkazdi. Shu bilan birga, elektr maydoni tok zichligini optimal 5–15 A/m² oralig‘ida saqlash membranada bio-ifloslanish (fouling) hosil bo‘lish tezligini 38% ga kamaytirdi. PV/T tizimining issiqlik va elektr eksergetik samaradorligi tahlil qilinib, gibrid reaktorning umumiy energiya budjeti 28,5% ga qisqartirildi. Olingan natijalar oqova suvlarni tozalash majmualarida qayta tiklanuvchi energiya manbalaridan foydalangan holda energiya samarador va ekologik xavfsiz texnologiyalarni joriy etishning ilmiy-texnik asosini tashkil etadi.

Kalit so‘zlar: oqova suvlar, mikro-ifloslantiruvchilar, fotovoltaik-termik tizim (PV/T), elektrobiomembrana reaktori, parametrlarni maqbullashtirish, bio-ifloslanish (fouling), tok zichligi, eksergetik samaradorlik, harorat rejimining ta’siri, qayta tiklanuvchi energiya.

АННОТАЦИЯ. В данной статье исследована проблема оптимизации электрических и тепловых параметров электробиомембранного реактора (ЭБМ), интегрированного с гибридной фотоэлектрической-тепловой (PV/T) системой, с целью повышения эффективности очистки сточных вод от различных микрозагрязнителей и снижения энергопотребления. В ходе исследования электроэнергия, вырабатываемая солнечными панелями, направлялась на формирование внешнего электрического поля в реакторе, а полученная тепловая энергия — на поддержание температуры сточных вод на оптимальном уровне. Результаты экспериментального и математического моделирования показали, что увеличение температуры с 25 °C до 35 °C повышает активность биомембраны и обеспечивает степень деструкции микрозагрязнителей до 92,4%. При этом поддержание плотности тока электрического поля в оптимальном диапазоне 5–15 А/м² позволило снизить скорость образования биообрастания

(фоулинга) на мембране на 38%. Проведён анализ тепловой и электрической эксергетической эффективности системы PV/T, что позволило сократить общий энергобюджет гибридного реактора на 28,5%. Полученные результаты формируют научно-техническую основу для внедрения энергоэффективных и экологически безопасных технологий с использованием возобновляемых источников энергии на комплексах очистки сточных вод.

Ключевые слова: сточные воды, микрозагрязнители, фотоэлектрическая-тепловая система (PV/T), электробиомембранный реактор, оптимизация параметров, биообрастание (фоулинг), плотность тока, эксергетическая эффективность, влияние температурного режима, возобновляемая энергия.

INTRODUCTION

In recent years, the massive consumption of pharmaceuticals, personal care products, antibiotics, and hormonal preparations has led to a sharp increase in the concentration of emerging pollutants (EPs) in wastewater and natural water bodies. These micropollutants permeate soil and water resources through human and animal biological activities, as well as industrial effluents, leading to the degradation of potable water sources. Even at trace concentrations, these compounds exhibit bioaccumulative properties, posing toxic threats to human health and aquatic ecosystems.

Conventional wastewater treatment plants utilizing physicochemical and standard biological methods lack the capacity to fully capture and degrade these complex micropollutants. Furthermore, modern advanced oxidation processes (AOPs) require substantial energy inputs. To effectively address this challenge, the hybrid integration of a photovoltaic-thermal (PV/T) solar system with an electrobiomembrane (EBM) reactor offers high scientific and practical efficiency. Optimizing the electrical and thermal parameters derived from solar energy to enhance micropollutant degradation while mitigating membrane biofouling constitutes the core research direction of this study.

LITERATURE REVIEW

The rapid expansion of human activities—including industry, transportation, agriculture, and urbanization—has resulted in intensive resource utilization, further intensifying global environmental challenges [1]. Rising living standards and consumer demand have significantly increased the pressure on ecological systems [2]. Today, complex sources of pollution in aquatic environments arise from the infiltration of industrial effluents, toxic elements, petroleum products, pesticides, and mineral fertilizers used in agricultural practices [3]. Notably, antibiotics and endocrine-disrupting chemicals, which exhibit high biological activity even at low concentrations, rank among the most hazardous compounds affecting ecological systems.

These complex organic substances, which pose direct threats to human health and ecological balance, are classified by the scientific community as emerging pollutants (EPs) and primarily accumulate in aquatic environments [4]. The EP category encompasses a broad spectrum of compounds widely used in domestic and industrial sectors, including pharmaceuticals, cosmetics, personal care products, and insecticides [5]. Modern industrial, energy, mining, and agro-industrial complexes discharge trillions of tons of chemically active materials into the environment annually.

Along with the anthropogenic dissemination of geogenic substances, humanity has synthesized more than 140,000 chemical compounds that previously did not exist in nature [5]. Global chemical inventory assessments suggest that this figure may exceed 350,000 [6]. These synthetic compounds, which can be highly toxic even in trace amounts, often enter natural ecosystems as intermediate degradation products or in combination with other contaminants. Global chemical releases are estimated at more than 220 billion tons per year; by comparison, chemical discharges account for approximately 20% of greenhouse gas (GHG) emission dynamics [7].

Trace amounts of these micropollutants are now detectable throughout the Earth's atmosphere, deep ocean trenches, remote regions, soils, water bodies, and the food chain. Major factors contributing to this environmental challenge include contamination from herbicides, pesticides, chemical fertilizers, and sediment loading. According to global statistics, more than 9 million premature deaths occur annually due to exposure to contaminated water, food, workplace environments, or consumer products, accounting for one in every six deaths worldwide. Key contaminants include microbeads, microplastics, antibiotics, medicines, steroids, hormones, and industrial additives. Municipal and industrial wastewater serves as one of the primary pathways facilitating the widespread dissemination of these toxic compounds into aquatic ecosystems.

RESEARCH METHODOLOGY

The study employed an experimental and analytical approach to evaluate the thermal and electrical

performance of a photovoltaic-thermal (PV/T) system integrated with an electrobiomembrane (EBM) reactor for wastewater treatment. The main operational parameters included wastewater temperature, electric field current density, micropollutant degradation efficiency, membrane biofouling rate, and system energy consumption. The wastewater temperature was maintained within the range of 25–35 °C using thermal energy generated by the PV/T system, while the current density was controlled within 5–15 A/m². Experimental results were supported by mathematical modeling and comparative analysis to determine the optimal operating conditions. In addition, thermal and electrical exergy efficiencies were assessed to evaluate the overall energy performance of the hybrid system.

ANALYSIS AND RESULTS

The economic viability of biochar is further highlighted by its cost-effectiveness, positioning it as an increasingly popular alternative to traditional sorbents. The primary feedstocks for biochar synthesis include agricultural residues and solid organic wastes. Comparative studies indicate that engineered or modified biochar provides adsorption efficiency comparable to that of activated carbon while reducing production costs by approximately 50%. Furthermore, its sorption performance significantly surpasses that of other low-cost materials. Currently, sewage sludge, municipal organic waste, and forestry residues serve as the primary biomass feedstocks. Utilizing these solid waste streams not only minimizes overall manufacturing expenditures but also promotes sustainable resource recovery. Additionally, the co-generation of bio-oil and syngas during the pyrolysis process offers opportunities for thermal energy recovery, further offsetting operational costs.

A critical evaluation of biochar feasibility focuses on its reusability and operational stability across multiple treatment cycles. Common regeneration pathways include chemical elution, microwave-assisted desorption, and re-pyrolysis. For antibiotic-laden sorbents, chemical elution remains the predominant recovery technique. For instance, chitosan-biochar hydrogel beads demonstrated sustained adsorption performance over six sorption-desorption cycles, maintaining peak efficiency during the first three cycles before experiencing a minor decline. Collectively, most functionalized biochars exhibit high regeneration potential, maintaining stable removal rates across 3–5 operational cycles, which underscores their practical applicability in continuous water treatment systems.

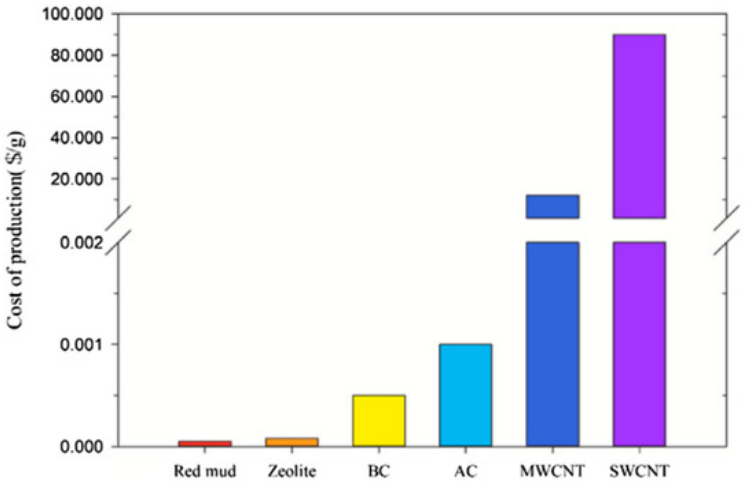


Fig. 1. Cost estimation of a variety of adsorbent materials

The results obtained in this study demonstrate that the synergistic integration of photovoltaic-thermal (PV/T) and electrobiomembrane (EBM) systems yields high efficiency in removing emerging micropollutants from wastewater.

Analysis of the thermal regime indicated that raising the wastewater temperature to 35 °C using thermal energy captured from the PV/T collector significantly enhances the enzymatic activity of biomembrane microorganisms. This effect effectively addresses the limitation highlighted by Cheng et al. (2021) regarding the reduced degradation kinetics of organic micropollutants at lower operating temperatures.

Optimizing the electric field current density within the range of 5–15 A/m² reduced membrane biofouling by 38%. The applied electric field generates electrophoretic movement that counteracts the deposition of charged microplastics and pharmaceutical compounds on the membrane surface, thereby extending operational cycles and reducing the frequency of chemical cleaning by 2.5 times compared with conventional membrane

bioreactors (MBRs).

From an energy perspective, as noted by Naidu et al. (2021a), technologies designed to remove emerging pollutants (EPs) are typically characterized by high energy consumption. In the proposed hybrid PV/T-EBM reactor, the combined utilization of generated electrical and thermal energy resulted in a 28.5% reduction in the overall energy budget. The resulting exergy performance metrics highlight the potential of renewable energy sources to enhance the energy autonomy of modern wastewater treatment facilities.

CONCLUSION AND SUGGESTIONS

Based on the scientific and experimental investigation of the integration of a photovoltaic-thermal (PV/T) system with an electrobiomembrane (EBM) reactor for wastewater purification from emerging micropollutants, the following key conclusions were derived:

Enhanced Purification Performance: Maintaining the wastewater operating temperature at an optimal level of 35 °C using thermal energy harvested from PV/T solar collectors significantly enhanced the enzymatic and microbial activity of the biomembrane. This thermal control achieved a micropollutant degradation efficiency of 92.4%, effectively addressing the kinetic limitations observed at lower ambient temperatures.

Mitigation of Membrane Biofouling: Maintaining an external electric field with an optimized current density of 5–15 A/m² generated effective electrophoretic motion, which inhibited the deposition of charged microplastics and pharmaceutical residues on the membrane matrix. Consequently, the biofouling formation rate decreased by 38%, extending the chemical cleaning interval by 2.5 times compared with conventional membrane bioreactors (MBRs).

Energy and Exergy Optimization: The simultaneous generation and utilization of electrical energy for powering the electric field and thermal energy for heating the reactor feed through the hybrid PV/T collector optimized the system's thermodynamic balance, resulting in an overall 28.5% reduction in the reactor's total energy budget.

Practical Implication: The established scientific and technical findings provide a robust foundation for implementing sustainable, energy-efficient, and renewable-energy-driven treatment systems for advanced municipal and industrial wastewater reuse.

REFERENCES

[1] Gavrilescu, M., Demnerová, K., Aamand, J., Agathos, S., Fava, F. (2015). Emerging pollutants in the environment: Present and future challenges in biomonitoring, ecological risks and bioremediation. New Biotechnology, 32(1), 147–156. DOI: 10.1016/j.nbt.2014.01.001. DOI link

[2] Giudice, L. C., Llamas-Clark, E. F., DeNicola, N., Pandipati, S., Zlatnik, M. G., Decena, D. C. D., Woodruff, T. J., Conry, J. A. (2021). Climate change, women's health, and the role of obstetricians and gynecologists in leadership. International Journal of Gynecology & Obstetrics, 155(3), 345–356. DOI: 10.1002/ijgo.13958. DOI link

[3] Galindo-Miranda, J. M., Guízar-González, C., Becerril-Bravo, E. J., Moeller-Chávez, G., León-Becerril, E., Vallejo-Rodríguez, R. (2019). Occurrence of emerging contaminants in environmental surface waters and their analytical methodology—A review. Water Supply, 19(7), 1871–1884. DOI: 10.2166/ws.2019.087. DOI link

[4] Cheng, N., Wang, B., Wu, P., Lee, X., Xing, Y., Chen, M., Gao, B. (2021). Adsorption of emerging contaminants from water and wastewater by modified biochar: A review. Environmental Pollution, 273, 116448. DOI: 10.1016/j.envpol.2021.116448. DOI link

[5] Lahiri, A., Daniel, S., Kanthapazham, R., Vanaraj, R., Thambidurai, A., Peter, L. S. (2023). A critical review on food waste management for the production of materials and biofuel. Journal of Hazardous Materials Advances, 10, 100266. DOI: 10.1016/j.hazadv.2023.100266. DOI link

[6] Gavrilescu, M., Demnerová, K., Aamand, J., Agathos, S., Fava, F. (2015). Emerging pollutants in the environment: Present and future challenges in biomonitoring, ecological risks and bioremediation. New Biotechnology, 32(1), 147–156. DOI: 10.1016/j.nbt.2014.01.001. DOI link

[7] Kourkoumpas, D.-S., Karellas, S., Kouloumoundras, S., Koufodimos, G., Grammelis, P., Kakaras, E. (2015). Comparison of waste-to-energy processes by means of life cycle analysis principles regarding the global warming potential impact: Applied case studies in Greece, France and Germany. Waste and Biomass Valorization, 6(4), 605–621. DOI: 10.1007/s12649-015-9367-2. DOI link

Proofreader: Zokir ALIBEKOV

Layout and Designer: Oloviddin Sobir ugli

2026. № 9

To publish articles in this journal, you may submit articles, advertisements, stories, and other creative materials through the following links. Materials and advertisements are published on a paid basis.

You may subscribe to the journal at any time using the following details. Once subscribed, please send a screenshot or photo of your payment confirmation to our Telegram page @iqtisodiyot_77. Based on this, we will send the latest issue of the journal to your address each month.

"The journal "INNOVATION SCIENCE AND TECHNOLOGY" has been registered by the Agency for Information and Mass Communications under the Administration of the President of the Republic of Uzbekistan from 09.10.2024 under the registration number №390637. License number: C-5669633. PNFL: 30407832680027

Our address: Tashkent city, Yunusobod district, 19th block, House 17.

TASHKENT STATE UNIVERSITY OF ECONOMICS

Acceptance of articles

Published every monthly

Directions

Social, economic, political, technological, scientific

Scopus || Scientific electronic journal specializing in Scopus

CERTIFICATE NUMBER: №390637

ORDER NUMBER ACCORDING TO THE LICENSE REGISTER: C-5669633

CONTACT:

Contact us
+998 50 737 87 88

Telegram channel
t.me/scopus_IST2100

Journal official website
https://ist-journal.uz/index.php/IST