frontiers | Frontiers in Chemical Engineering

TYPE Editorial
PUBLISHED 15 May 2024
DOI 10.3389/fceng.2024.1412081

OPEN ACCESS

EDITED AND REVIEWED BY
J. Paul Chen,
National University of Singapore, Singapore

*CORRESPONDENCE
Santhana Krishnan,
santhana.k@psu.ac.th

RECEIVED 04 April 2024
ACCEPTED 23 April 2024
PUBLISHED 15 May 2024

CITATION
Krishnan S, Nasrullah M, Saravanan P and Bin Md Din MF (2024), Editorial: Bioprocess designing towards clean energy production from industrial wastewater.
Front. Chem. Eng. 6:1412081.
doi: 10.3389/fceng.2024.1412081

Editorial: Bioprocess designing towards clean energy production from industrial wastewater

Santhana Krishnan[1]*, Mohd Nasrullah[2], Prabhu Saravanan[3] and Mohd Fadhil Bin Md Din[4]

[1]Department of Civil and Environmental Engineering, Faculty of Engineering, Prince of Songkla University, Songkhla, Thailand, [2]Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, Kuantan, Pahang, Malaysia, [3]Department of Physical-Chemistry, Faculty of Chemical Sciences, University of Concepcion, Concepción, Chile, [4]Department of Water and Environmental Engineering, University of Technology Malaysia, Johor Bahru, Malaysia

KEYWORDS

bioenergy, biofuels, GHG reduction, bio-electrochemical systems, bioreactors, wastewater treatment

Editorial on the Research Topic
Bioprocess designing towards clean energy production from industrial wastewater

Highlights

This Research Topic received 12 submissions.
The best submissions were published after undergoing peer review assessment.
This Research Topic has enhanced understanding of fundamental scientific concepts addressed.

1 Introduction

The finite nature of fossil fuel-based energy sources, the significant rise in waste generation, and the growing requirement for alternative energy and chemicals have led to the necessity of a waste-derived bioeconomy. Due to the difficult decarbonization objectives, there has been a worldwide focus on the use of bioengineering and bioprocess technology in the past few decades. These technologies aim to replace fossil fuel-based technologies and promote clean energy, waste management towards environmental sustainability. Bioprocesses have significant implications in integrating environmental management methods, including biomass valorization, wastewater treatment, solid waste management, potential nutrient recovery and renewable energy production as depicted in Figure 1. In view of that, the current Research Topic, titled "*Bioprocess designing towards clean energy production from industrial wastewater*," aims to gather recent scientific advancements in the field of environmental bioprocess and sustainable alternative energy. The current Research Topic (RT) addresses areas such as emerging energy and environmental technologies, biorefinery, biomass valorization, microbial bioprocess design,

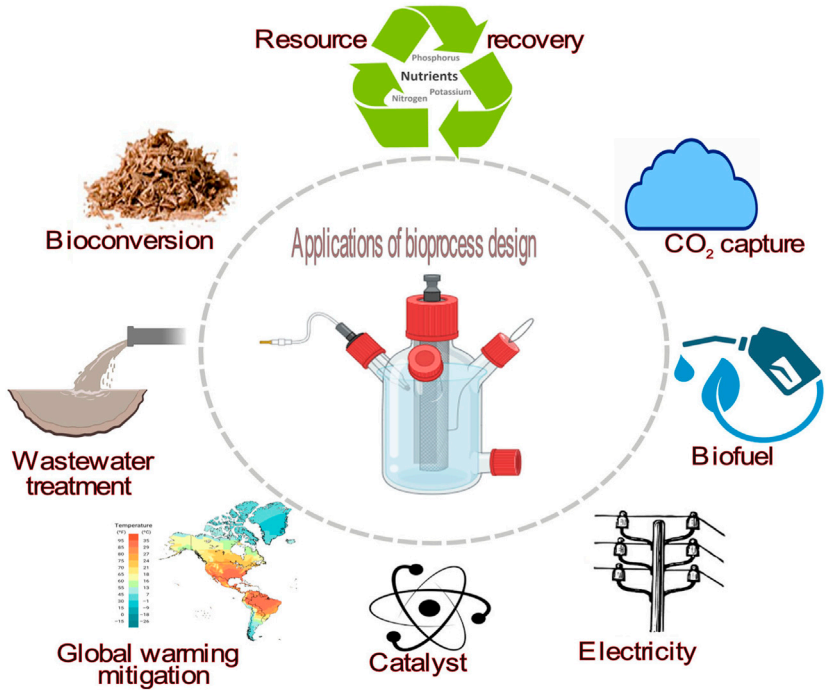

FIGURE 1
Sustainable environmental applications of bioprocess design.

bioconversions, biofuels, wastewater treatment, resource recovery, and energy storage. The manuscripts are chosen in the RT to cover an extensive choice of emerging themes in Bioprocess Engineering. The Editors believe that the outcome comprises a collection of highly intriguing papers that enhance understanding of the subject matter, and would be valuable for researchers and society as a whole.

2 Details of published articles on the Research Topic

Study 1: Due to the rising need for alternative fuels, microalgae have emerged as a feasible source that can provide high lipid content and a variety of other important chemicals. Therefore, Kumar et al. studied algae-based biodiesel production with an emphasis on its unit operations (both upstream and downstream) starting from strain selection, cultivation system, reactor operations, harvesting, and extraction of oil to biodiesel production. The strategies to enhance lipid accumulation by incorporating genetic, and metabolic engineering and harnessing bio-products nanoparticles, biofertilizers, biochar, and biopharmaceuticals have been addressed in detail.

Study 2: Microalgae is highly adaptable to the environment and has a high tolerance to various environmental stresses, however, their growth, Co_2 sequestration ability, and lipid accumulation are mainly influenced by the same stresses. To determine the physiological responses, Euglena gracilis was studied against environmental stresses (antibiotics, heavy metals, salinity), carbon resources (glucose and ethanol), potential for higher quality, yield of fatty acid with a high growth rate, and biodiesel properties were evaluated. Further, transcriptome analysis was used to investigate the regulation and production of fatty acids in various conditions to enhance biodiesel production. Treating TFA with glucose is very efficient and can be a good topic for detailed study in biodiesel synthesis. Transcriptome analyses indicate that optimal biodiesel production in E. gracilis can be attained through precise cultivation conditions that balance growth and photosynthesis (He et al., 2022).

Study 3: In recent days, herbicides such as glyphosates and chloroacetanilide classes have been extensively used in agricultural activities in the Indian nation to save crops from a variety of insects but their potential toxicity toward the non-target organisms, was equally reported to aquatic ecosystems. In this context, Mohanty and Jena (2022) investigated the biodegradation of the herbicide Butachlor belonging to the chloroacetanilide class using a synthetic microbial consortium, SMC1 embedded on ceramic raschig rings within a packed-bed bioreactor (PBBR). The authors used response surface methods to optimize the reactor's operational conditions. For the controlled biofilm-mediated reactions, they reported an optimal loading range (270–325 mg/l/d), COD removal (90%), flow rate (2.9 mL/min), herbicide concentration (454.63 mg/mL), nitrogen load (1,041 mg/L), for the maximal biodegradation of herbicides.

Study 4: Bioelectrochemical Systems (BES) are suggested as a substitute for traditional wastewater treatment, serving as either a main bioremediation method or for secondary wastewater treatment systems. Microbial fuel cells (MFCs) in bioelectrochemical systems (BES) utilize the metabolic ability of anodophilic (anode aspiring) bacteria to break down the organic material found in wastewater and simultaneous electricity production. In this perspective, Agudelo-Escobar et al. (2022) analyzed the capacity of indigenous microbial communities to break down organic substances in coffee industrial effluent and assessed its ability to generate electricity through an

MFC. MFC with 200 mL anodic chamber was operated in a fed-batch, open and closed-circuit conditions, for 60 days to bioremediate the coffee effluent and by measuring the physicochemical parameters, native microbial community characterization, and electrogenic potential of anodophilles. The proposed system was able to reduce 70% of the organic matter and 400 mV of open circuit voltages were recorded.

Study 5: Similarly, Babanova et al. (2022) reported a bioelectrochemical treatment technology (BETT) prototype system at a major brewery in Los Angeles, CA, United States. The system processes 0.6 m^3 per day of raw brewery effluent containing a significant amount of fruit pulp. Greenhouse gas emissions linked to power consumption, biomass production, and carbon dioxide release were calculated and contrasted with aerobic and anaerobic alternatives. BETT demonstrated a 33% reduction in total COD at 4 h s hydraulic retention time (HRT) and overall Co_2 emission reduction was estimated to be 85%–90% compared to aerobic and anaerobic alternatives.

Study 6: It is crucial to promptly develop and select appropriate cathode materials for the actual implementation of Microbial Fuel Cells (MFCs) in the current scenario. Therefore, Elangovan et al. (2023) reviewed the significant breakthroughs in oxygen reduction reaction (ORR) electrocatalysts including precious metals-based catalysts, non-precious metals-based catalysts, non-metals and carbon-based catalysts, and biocatalysts. Notable results for their application in microbial fuel cells (MFC), challenges, and prospects are critically discussed.

Study 7: Wastewater treatment technology based on the circular economy offers the most sustainable solutions for water pollution in developing nations. A new decentralized controller called Multi-Objective Decentralized Controller (MODC) is proposed for evaluating a Multi-Input Multi-Output (MIMO) activated sludge wastewater treatment plant (WWTP) to attain the highest effluent quality at the lowest cost (Subbian et al., 2023). A MIMO model was created for the activated sludge process (ASP). Relative gain array (RGA) analysis was conducted to assess loop interactions for selecting an appropriate control system. A MODC problem was defined to address the conflicting objectives of enhancing effluent quality and reducing operational costs through energy-efficient practices. Non-Dominated Sorting Genetic Algorithm II (NSGA-II) yielded several optimal solutions on the Pareto front. Enhancing effluent quality boosts active sludge generation, leading to increased methane output in the anaerobic digester.

Study 8: Lignin is regarded as a top substitute in future energy, fuel, and chemical industries. Exploring lignin's technical and economic potentials can unlock sustainable biorefineries and lead to a sustainable economy. In this context, Jassal et al. (2022) analyzed the potential of lignin as a developing substitute for petroleum and the current challenges in the commercialization process. The mini-review highlighted the need, potential, and emergence of lignin biopolymers, their extraction methods, and cost-reduction strategies were overviewed.

Study 9: Highly promising decarbonized fuels include hydrogen (H_2) with no pollutants released during direct combustion or fuel cell oxidation. Industrial production of H_2 relies on energy-intensive hydrocarbon reformation, which detracts from its environmental advantages and limits its use as a fuel. Hydrogen sulfide (H_2S) is an alternate source of H_2 that is often ignored. In this dimension, Velazquez-Rizo and Cavazos Sepulveda (2023) discussed the progress in the direct electrochemical separation of H_2S below the sulfur dew point, with a focus on the growing significance of sulfur poisoning. The review article explored several technologies, underlying mechanisms, and approaches employed to improve the energy efficiency and stability of H_2S electrolytic systems, including nanostructured electrodes and novel sulfur solvents utilized as electrolytes.

Study 10: Membrane distillation crystallization is an innovative technology that aims to recover water and minerals at the same time to address the difficulties encountered by the desalination sector. MDC continues to encounter obstacles in utilizing its industrial applications because of membrane fouling, scaling, and wettability issues. Hence, the study by Chimanlal et al. (2022) examined the occurrence of membrane fouling and wetness in MDC. Furthermore, parameter optimization, fouling control methods, and current advancements made to tackle these difficulties are thoroughly evaluated. Finally, the potential for the sustainability of this technology is emphasized.

Study 11: It is important to reassess energy security considerations and priorities in the context of climate change through the development of an economic model. In this analytical framework, Shayegh (2023) investigated how energy security policy and climate stability are influenced by imported natural gas, regional coal output, and potential direct air capture (DAC) deployment in the European Union (EU) under two intersections: full integration and full competitiveness among EU member states. The interesting findings indicated that full cooperation of the EU leads to increased dependence on imported energy but also creates a strong motivation for DAC adoption. Competition, however, could lead to increased dependence on domestic coal production and exacerbate climate change issues, even with the presence of DAC.

3 Perspectives for future

Study 1: Deployment of mass cultivation strategies, high-yielding algal strains, sustainable downstream processing, and commercial viability are some of the key areas to be focused on.

Study 2: It is recommended to utilize experimental validations such as gene knockdown or overexpression studies to confirm the functions of individual genes found through transcriptome analysis.

Study 3: Packed-bed bioreactor removal efficiency was mainly influenced by the retention period, initial loading rates, and substrate concentration. Integration of artificial intelligence (AI) mediated bioprocess optimization can enhance further yield and overall removal efficacy.

Study 4: Although microbial fuel cells (MFCs) hold potential, their application in large-scale wastewater treatment is hindered by the cost of electrode materials and other sustainable challenges. Current research must be aimed to overcome these obstacles to enhance the technology's efficiency and economic feasibility.

Study 5: It is recommended to conduct more large-scale pilot plants to validate the potential of coupling BES with carbon capture and utilization technologies beyond wastewater treatment.

Study 6: Improvements in the stability and effectiveness of the ORR electrocatalysts are essential for the practical application of

MFCs. Further experimental and theoretical study is needed to apply the successful performance of air-cathode MFCs in laboratory settings to practical applications.

Study 7: Before implementing, identify decision variables, establish communication protocols, and undertake thorough simulations to confirm the MODC's performance in several scenarios.

Study 8: Lignin extraction and purification are too intricate and expensive for large-scale application. Problem-solving requires accelerating technologies and cooperating across catalysis, chemical engineering, and analytics.

Study 9: Exploring sustainable and novel catalyst regeneration methods, such as subjecting the electrocatalysts to chemical or thermal treatment to revive their catalytic sites.

Study 10: Manufacturing membranes with eco-friendly reagents, refining membrane cleaning methods, and doing pilot-scale research to assess MDC applicability.

Study 11: Future studies could enhance this analysis by including additional stakeholders, exploring different energy alternatives, and utilizing more advanced climate change models.

4 Conclusion

The Guest Editors would like to extend their heartfelt gratitude to the Editor-in-Chief of Frontiers in Chemical Engineering, the Managing Editor, the Journal Managers, the Associate Publishing Content Specialist, and the entire team for their invaluable guidance and assistance, which greatly contributed to the success of this RT. The Guest Editors express their gratitude to all the authors for submitting their exceptional works and to the reviewers for their important remarks and suggestions. Devoid of these contributions, the complete completion of this RT would not have been possible. The articles in this RT are top-notch contributions that enrich scholarly understanding of the discussed Research Topic. The Editors of the current RT *Bioprocess designing towards clean energy production from industrial wastewater* aim to stimulate more research on the problem and facilitate the dissemination of new discoveries.

Author contributions

SK: Writing–review and editing, Writing–original draft, Visualization, Supervision, Project administration, Investigation, Formal Analysis, Data curation, Conceptualization. MN: Resources, Writing–review and editing, Validation, Formal Analysis. PS: Writing–review and editing, Validation, Formal Analysis. MB: Writing–review and editing, Validation, Formal Analysis.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

This study was supported by the Postdoctoral Fellowship from Prince of Songkla University, Thailand.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note