



## An evaluation of the ecological effect of algae based fuel production review

S Vijaya

Head and Assistant Professor, Department of Botany, Tara Govt. College (A), Sangareddy, Telangana, India

### Abstract

The ecological effects of algae-based fuel production have gained considerable attention in recent years due to the growing need for sustainable and renewable energy sources. Algae-based biofuels are considered a promising alternative to traditional fossil fuels, as they have the potential to reduce greenhouse gas emissions and mitigate some of the environmental challenges associated with conventional fuel production. This review aims to provide a comprehensive assessment of the ecological impacts associated with algae-based fuel production. Algae are known for their rapid growth and high oil content, which makes them an attractive feedstock for biofuel production. This advantage is often touted to reduce carbon emissions, as algae absorb carbon dioxide during photosynthesis and can potentially offset emissions from burning their oil-based biofuels. Additionally, algae cultivation can use non-arable land and wastewater, reducing pressure on valuable agricultural resources. However, the ecological effects of algae-based fuel production are not without their challenges. It is crucial to evaluate and manage potential negative consequences, such as nutrient runoff and the introduction of non-native algae species in natural ecosystems. Algae cultivation requires water, nutrients, and suitable environmental conditions, which can lead to competition for freshwater resources, eutrophication, and potential harm to aquatic ecosystems. The use of synthetic chemicals in algae cultivation, such as pesticides and fertilizers, can also have adverse ecological impacts. Furthermore, the land use and infrastructure required for large-scale algae cultivation should be carefully planned to prevent habitat destruction and loss of biodiversity. The energy and resources consumed during the cultivation, harvesting, and processing of algae into biofuels should be analysed to assess their environmental footprint.

This review will examine existing research and literature to provide a comprehensive evaluation of the ecological effects of algae-based fuel production. By synthesizing the current knowledge, it aims to shed light on the trade-offs and potential solutions for mitigating the environmental impacts associated with this promising biofuel source. The conclusions drawn from this review will help guide future research and development in the field of algae-based biofuels, with the goal of minimizing their negative ecological effects while harnessing their environmental benefits. Concerns about the rapid depletion of fossil fuels, energy security, climate change due to global warming, environmental pollution, and faster increase of fossil fuel prices have drawn attention to researchers, the scientific community, and government policymakers to develop alternative energy sources for reducing dependence on fossil fuel. In recent years, microalgae culture has received significant attention due to its potential application for bioenergy production, wastewater treatment, industrial CO<sub>2</sub> removal, and production of biochemical compounds that can be used for human and animal health and other benefits. However, large-scale microalgae production and their processing for producing various products and by-products could have environmental impacts beyond energy consumption in the microalgal production process. This article has reviewed the environmental effects of microalgae-based biofuel production on water resources and quality, eutrophication, biodiversity, waterborne toxicants, algal toxicity, wastewater remediation or treatment, waste generation, and greenhouse gas land-use changes, and genetically engineered microalgae.

**Keywords:** Algae-based biofuels, ecological impact, sustainability, carbon footprint, greenhouse gas emissions, algae cultivation, biodiversity, eutrophication

### Introduction

The need for primary energy has expanded significantly due to the continual expansion of the world population, particularly during the past 50 years. According to SRWE (2021), there was a notable rise in worldwide primary energy consumption from 505.38 exajoules in 2010 to 581.51 exajoules in 2019. According to the SRWE (2021), the Covid-19 epidemic resulted in a decrease in primary energy consumption, which amounted to 556.63 exajoules in the year 2020. Nevertheless, it is anticipated that world economic activity and energy consumption will return to pre-COVID-19 levels by the conclusion of 2021, owing to the implementation of an expanded vaccination programme and the implementation of strategic lockdown measures. The global community is currently confronted with two significant difficulties because of escalating energy

consumption: an energy crisis and environmental degradation (Gupta and Tuohy, 2013)<sup>[16]</sup>.

The combustion of fossil fuels is accountable for the release of greenhouse gases, notably carbon dioxide (CO<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and carbon monoxide (CO). The emission of greenhouse gases has experienced a gradual increase because of the widespread use of fossil fuels in both power generation and transportation, leading to elevated levels of carbon dioxide (CO<sub>2</sub>) being released into the atmosphere. According to SRWE (2021), the worldwide CO<sub>2</sub> emissions saw an increase from around 31.29 billion tonnes in 2010 to over 34.36 billion tonnes in 2019. This rise in emissions has been associated with a significant impact on global warming, as highlighted by Hosseini *et al.* (2013)<sup>[20]</sup>. Global warming has been seen as a significant and pressing issue. In recent times, the consequences of

global warming have resulted in significant harm to both the human and natural ecosystems (Lam *et al.*, 2012) [25]. Hence, it is imperative to mitigate carbon dioxide emissions promptly to avert the adverse consequences associated with global warming. Therefore, there has been a significant increase in the focus on the advancement of CO<sub>2</sub> capture and sequestration technologies to effectively decrease CO<sub>2</sub> emissions from a wide range of sources, including industrial flue gas and vehicle exhaust emissions (Lam *et al.*, 2012) [25]. The user provided a numerical reference (Lam *et al.*, 2012) [25].

Since the 1970s, oil and gas corporations have undertaken the practise of injecting carbon dioxide (CO<sub>2</sub>) into oil reservoirs to improve the recovery of oil (Kovscek and Cakici, 2005) [23]. Researchers are now engaged in active exploration of biomasses to extract energy from renewable sources. The process of photosynthesis is widely recognised for its ability to facilitate the conversion of solar energy into chemical energy in plants. Microalgae have superior photosynthetic efficiency compared to other crops, with a magnitude ranging from 10 to 50 times larger than that of terrestrial plants. Additionally, microalgae demonstrate rapid growth rates, surpassing those of terrestrial plants by a factor of 100. According to (Tredici 2010) [45], the rate at which they can increase their biomass is such that they can achieve a doubling during a period of less than 24 hours. Khan *et al.* (2009) [21] conducted a study. Furthermore, these organisms possess the remarkable ability to acclimatise to highly challenging aquatic environments and efficiently assimilate advantageous chemical compounds. In addition, it is worth noting that microalgae cells include a carbon content of roughly 50%. Moreover, according to Yusuf (2007) [48], these cells can sequester 1.8 kg of CO<sub>2</sub> through the production of 1 kilogramme of microalgae biomass. Furthermore, the ability to synthesise enough amounts of carbohydrates (sugars) and fat (triacylglycerides) necessary to produce bioethanol and biodiesel varies depending on the species and growing circumstances. Microalgae possess proteins that might potentially serve as a viable alternative for animal feed. Certain species could synthesise a diverse range of economically valuable compounds, including carotenoids, EPA, DHA, astaxanthin, phycocyanins, polyphenol pigments. These compounds have potential applications in various industries such as nutraceuticals, cosmeceuticals, pharmaceuticals, aquatic and terrestrial animal husbandry, and the food industry. The utilisation of these compounds could enhance the commercial feasibility of biofuel production (Obin and Alam, 2017; Mobin and Alam, 2018) [34].

### **The impact of algae that culture on the natural environment**

The cultivation of algae in natural contexts can exert substantial influences on ecosystems and the adjacent habitats. It is imperative to consider the various repercussions, both positive and negative, that arise from the implementation of algae production. Gaining a comprehensive understanding of the ramifications associated with algae cultivation is crucial to make well-informed decisions and promote responsible and sustainable practises. This article examines the ecological consequences of algae cultivation on the natural environment, while also citing relevant sources that substantiate these effects.

### **Positive impacts**

There are several positive effects that can be attributed to a particular phenomenon or event. These positive impacts can bring. The production of algae in natural contexts has the potential to provide several beneficial ecological outcomes. Algae exhibit a high degree of proficiency in the process of nutrient uptake, namely in the removal of surplus nitrogen and phosphorus from aquatic environments (Liu *et al.*, 2017) [27]. This procedure aids in mitigating eutrophication, a prevalent ecological concern resulting from the introduction of excessive nutrients into an ecosystem. Algae are known to contribute to the process of carbon sequestration, specifically in the domain of carbon capture and storage. According to Chiu *et al.* (2015) [9], plants can uptake carbon dioxide through the process of photosynthesis, thereby contributing to the reduction of greenhouse gas emissions. Algae play a significant role in the process of oxygen creation by means of photosynthesis. According to Mata *et al.* (2010) [30], the enrichment of oxygen in water has the potential to improve water quality and provide support for aquatic organisms.

### **The adverse effects**

Nevertheless, the cultivation of algae can also result in adverse consequences for natural ecosystems. Unregulated proliferation of algae can result in the occurrence of hazardous algal blooms (HABs), which can release toxins that adversely affect aquatic organisms and represent potential health hazards to human beings (Anderson *et al.*, 2002) [1]. Harmful algal blooms (HABs) have the potential to destabilise ecosystems and inflict significant damage.

### **Habitat modification**

The production of algae on a large scale has the potential to modify natural habitats, hence potentially causing disruptions to the ecological balance (Xie *et al.*, 2019) [47]. Alterations in water quality and habitat have the potential to exert an impact on indigenous species and their reproductive environments. The cultivation of algae in non-native habitats can result in competition with native species for resources, leading to potential consequences for biodiversity and the food chain (Salmaso *et al.*, 2018) [39]. The susceptibility of algal culture systems to illnesses and viruses can potentially constitute a harm to the natural environment (Carney *et al.*, 2014) [7]. The study and implementation of strategies for the effective control and reduction of negative impacts. To mitigate the adverse effects and optimise the advantages of algae cultivation in natural ecosystems, various approaches can be implemented: The implementation of a comprehensive monitoring system is crucial to effectively identify and address any potential negative impacts on water quality, algae proliferation, and overall environmental conditions (Behera *et al.*, 2018) [3]. Regulation plays a crucial role in the management of algae culture in natural habitats by implementing and enforcing guidelines and regulations. This approach is essential for mitigating any negative consequences, as highlighted by Smith *et al.* (2008) [41]. The careful selection of algal strains is of utmost importance to mitigate the potential risks associated with invasive species and ecological disruption (Hallegraeff, 2010) [18]. The selection of non-invasive species and strains that are

appropriately adapted to the local environment is of utmost importance.

In summary, the effects of algae farming on the natural environment are diverse, encompassing both advantageous and detrimental outcomes. The overall impact of algae cultivation is significantly influenced by factors such as the scale, location, and management practises employed in the process. To achieve sustainable and responsible cultivation of algae in natural ecosystems, it is imperative to use a comprehensive approach that considers the ecological ramifications and implements measures to minimise potential adverse impacts.

### **Water resources and water quality (release of cultural and process water)**

The discharge of cultural and process water into water bodies can have substantial consequences for both water quality and the surrounding ecosystem. The release of water from diverse industrial, agricultural, and municipal operations has the potential to introduce pollutants and disturb the ecological equilibrium of aquatic ecosystems. The literature provides several significant findings concerning the effects of these emissions on the quality of water and water resources. Industrial effluents refer to the liquid waste materials that are discharged from industrial processes. Industrial wastewater frequently comprises a diverse array of contaminants, encompassing heavy metals, organic compounds, and chemical substances. The discharge of these effluents into aquatic environments has the potential to cause water pollution, resulting in detrimental effects on both aquatic organisms and human well-being (Metcalf & Eddy, 2013) [32]. Multiple research studies have emphasised the necessity of implementing rigorous rules and implementing efficient treatment methods for industrial wastewater to alleviate its detrimental effects on the quality of water (Saeidi *et al.*, 2019) [38].

The phenomenon of agricultural runoff refers to the process by which excess water, carrying various substances such as fertilisers, pesticides, and animal. Agricultural practises, including the application of fertilisers and pesticides, have the potential to cause the discharge of nutrients into water bodies, specifically rivers and streams. The discharge of excess water can result in the process of eutrophication, the occurrence of algal blooms, and a deterioration in the overall quality of water (Smith *et al.*, 1999) [40]. The significance of implementing best management practises in agriculture to mitigate nutrient pollution and safeguard water resources is underscored by research findings (Kladivko *et al.*, 2014) [22]. Municipal wastewater refers to the collective discharge of liquid waste from residential, commercial, and industrial sources within a municipality. The discharge of untreated or inadequately treated municipal wastewater has the potential to introduce pathogens, fertilisers, and organic debris into aquatic environments. The activities have the potential to result in the introduction of harmful substances, deterioration of the overall condition of water, and the transmission of diseases that are specifically transmitted by water (Mara & Pearson, 1998) [28].

Ensuring the preservation of water quality necessitates the adoption of effective sanitation infrastructure and the implementation of appropriate wastewater treatment measures (Mara *et al.*, 2007) [29]. Urban stormwater refers to the runoff of precipitation in urban areas, which can provide

significant challenges to water management and environmental sustainability.

Urban areas frequently produce substantial quantities of stormwater runoff, which possess the potential to transport various contaminants such as oil, heavy metals, and sediments into aquatic ecosystems. The potential consequences of this phenomenon include adverse effects on the quality of water and the delicate balance of aquatic ecosystems (Fletcher *et al.*, 2015) [13].

Researchers have observed that urban planners and engineers are actively investigating various approaches, such as the implementation of green infrastructure, to effectively address the management of stormwater and mitigate its negative impacts on water resources (Fletcher *et al.*, 2015) [13]. The topic of legislation and regulations pertains to the laws and rules that are established by governing bodies to govern various aspects of society.

The formulation and enforcement of water quality regulations are crucial to the implementation of effective water quality management. The objective of these laws is to regulate the discharge of contaminants into aquatic environments and establish criteria for water quality (Hornbuckle *et al.*, 2015) [19]. The implementation of comprehensive regulatory frameworks is necessary to effectively tackle water quality concerns and safeguard water resources (Smyth *et al.*, 2016) [42]. The topic of interest pertains to the monitoring and assessment of a certain subject matter. The regular monitoring of water quality metrics is crucial to assess the effects of cultural and process water discharges. The evaluation of water quality enables the identification of patterns and the application of remedial actions (Stewart *et al.*, 2018) [44].

The progress in technology and data analysis has significantly enhanced our capacity to monitor and evaluate the quality of water, hence facilitating more efficient management (Zhao *et al.*, 2017) [49]. In general, the discharge of cultural and process water into water bodies has significant implications for both water quality and the surrounding ecosystem. It is imperative to undertake endeavours aimed at mitigating pollution stemming from industrial, agricultural, municipal, and urban origins. The implementation of stringent laws, appropriate treatment methods, and sustainable practises plays a crucial role in the protection of water resources and the maintenance of a pristine and healthful water supply.

### **Utilisation of microalgae for wastewater cleanup**

Microalgae have gained popularity as a sustainable and effective method of wastewater treatment (Pulz & Gross, 2009) [37]. They are a promising technique for environmental remediation due to their unique capacity to extract nutrients and pollutants from wastewater. Microalgae are excellent at nutrient removal, assimilate nitrogen and phosphorus molecules such ammonia, nitrate, and phosphate (Liu *et al.*, 2017) [27]. This method lowers eutrophication and algae blooms in natural bodies of water. Microalgae can play an important role in pollutant removal in addition to nutrient removal. Some microalgae species can bioaccumulate heavy metals such as copper, lead, and cadmium, and they can metabolise organic pollutants such as pesticides, dyes, and hydrocarbons (Leng *et al.*, 2015) [26].

Microalgae also could store carbon dioxide during photosynthesis (Chiu *et al.*, 2015) [9]. This not only helps with wastewater treatment, but it also helps with carbon

capture and greenhouse gas reduction. Microalgae contribute to water quality improvement by creating oxygen during photosynthesis (Mata *et al.*, 2010) <sup>[30]</sup>. The aerobic conditions in wastewater treatment systems are improved by this technique. Microalgae biomass can be harvested from wastewater and used for a variety of uses, including biofuel generation, animal feed, and fertiliser (Gupta and Shrivastav, 2014) <sup>[17]</sup>. Microalgae development and harvesting are facilitated by algae-based wastewater treatment technologies such as algal ponds and photobioreactors (Mendez *et al.*, 2017) <sup>[31]</sup>. These systems are scalable and adaptable to unique wastewater treatment requirements. Borowitzka (2013) <sup>[5]</sup> found that incorporating microalgae into traditional wastewater treatment methods, such as activated sludge systems, can improve nutrient removal and overall treatment efficiency. For the optimal use of microalgae in wastewater treatment, careful monitoring, and control of environmental parameters such as pH, temperature, and light intensity are required (Behera *et al.*, 2018) <sup>[3]</sup>. Continuous research is required to identify and develop microalgae strains that are effective at removing nutrients and contaminants (Becker, 2007) <sup>[2]</sup>. To maximise the effectiveness of microalgae-based wastewater treatment, strain selection is crucial. Finally, given their nutrient and pollutant removal capabilities, carbon sequestration, and biomass production potential, microalgae provide a sustainable and environmentally beneficial alternative for wastewater cleanup.

#### **Microalgae scalability based on resource assessment**

The ability to scale up microalgae farming is intricately connected to the evaluation of available resources. The assessment of the accessibility of fundamental resources, such as water, nutrients, and appropriate land, plays a pivotal role in ascertaining the feasibility of extensive microalgae cultivation. The existing body of literature provides significant insights into the correlation between the scalability of microalgae and resource assessment.

#### **The object of discussion pertains to water resources**

Water is an essential resource for the cultivation of microalgae. The evaluation of the accessibility and calibre of water resources, encompassing both freshwater and brackish water, holds paramount importance in ascertaining the potential for expanding microalgae cultivation (Chinnasamy *et al.*, 2010) <sup>[8]</sup>. According to Pittman *et al.* (2011) <sup>[36]</sup>, the incorporation of wastewater or saline water can serve as a viable approach to mitigate the need for freshwater, hence augmenting the potential for expanding microalgae culture.

#### **The availability of nutrients**

Microalgae necessitate vital nutrients, specifically nitrogen and phosphorus, to facilitate their growth. Assessing the accessibility of these essential nutrients and their respective sources holds significant importance in the evaluation of scalability, as highlighted by Kumar *et al.* (2010) <sup>[24]</sup>. The evaluation of resources should encompass the examination of waste streams, such as agricultural runoff or industrial effluents, as potential sources of nutrients for the purpose of facilitating the production of microalgae on a wide scale (D'Este *et al.*, 2019) <sup>[10]</sup>.

#### **The topic of discussion pertains to land and infrastructure**

The relevance of land availability in the scalability of microalgae cultivation, including open ponds, photobioreactors, and raceway systems, has been highlighted in previous research (González-García *et al.*, 2015) <sup>[15]</sup>. According to Benemann (2013) <sup>[4]</sup>, when conducting an assessment, it is important to consider the infrastructure needs associated with large-scale cultivation. These needs encompass several aspects such as land preparation, containment systems, and harvesting facilities.

#### **The topic of discussion pertains to climate and environmental conditions**

The scalability of microalgae culture can be influenced by the local climate and environmental circumstances. The assessment of variables such as temperature, sunlight, and prevalent weather patterns is crucial (Borowitzka & Moheimani, 2013) <sup>[6]</sup>. The assessment of resources should also consider probable climate variations and their influence on the growth of microalgae throughout the year (Behera *et al.*, 2018) <sup>[3]</sup>. The economic feasibility or viability of a project or initiative is a crucial aspect that determines its potential for success in terms of financial sustainability and the economic viability of implementing large-scale microalgae production is contingent upon the accessibility of resources and the efficiency of cost management. The evaluation of costs associated with the acquisition of resources, such as water and nutrients, holds significant importance (Grima *et al.*, 2003) <sup>[15]</sup>. To improve scalability, it is imperative to conduct a comprehensive resource evaluation that encompasses the identification of economically viable and environmentally sustainable resource alternatives (Sørensen *et al.*, 2013) <sup>[43]</sup>.

#### **The topic of sustainability and its environmental impact is of great significance in academic discourse**

The concept of scalability should consider the responsible utilisation of resources to prevent their depletion or any adverse environmental consequences (Fábregas *et al.*, 2003) <sup>[12]</sup>. The exploration of sustainable resource management practises is crucial in conducting a resource assessment, as it aids in facilitating long-term scalability (Ometto *et al.*, 2019) <sup>[35]</sup>. One important aspect to consider when discussing this topic is the regulatory considerations.

Ensuring adherence to both local and national legislation is crucial for the successful implementation of large-scale microalgae farming. According to Eriksson *et al.* (2002) <sup>[11]</sup>, a comprehensive evaluation of resources should include a comprehension of the legal obligations associated with water utilisation, land utilisation, and waste management. In summary, the evaluation of resources plays a fundamental role in ascertaining the potential for scalability in the culture of microalgae. The process entails assessing the accessibility and long-term viability of fundamental resources, including water, nutrients, land, and climate conditions. A comprehensive comprehension of these aspects is crucial for the strategic development and execution of extensive microalgae cultivation.

#### **Conclusion**

The evaluation of the ecological effects of algae-based fuel production indicates a complicated interplay of environmental benefits and potential drawbacks. Because of

their ability to store carbon dioxide, reduce greenhouse gas emissions, and compete with food crops for arable land, algae-based fuels show promise as a sustainable alternative to fossil fuels. A full review, on the other hand, emphasises the importance of responsible and sustainable practises in algae culture and fuel generation to mitigate any ecological difficulties. On the positive side, algae production can provide enormous benefits to aquatic ecosystems. Algae can be utilised to clean wastewater by removing excess nutrients and contaminants from bodies of water, ultimately improving water quality, and supporting aquatic biodiversity. The ability of algae to survive in saline or brackish water helps alleviate the burden on freshwater resources, helping to ecological conservation. Furthermore, algae production can improve carbon sequestration, assisting in the lowering of atmospheric CO<sub>2</sub> levels. This technique is crucial in tackling climate change and its ecological consequences.

However, there are some challenges that must be addressed to assure the ecological sustainability of algae-based fuel production. Habitat degradation, especially when linked with large-scale farming systems, has the potential to alter local ecosystems and biodiversity. The usage of non-native algal strains or genetically engineered organisms may result in the introduction of invasive species that outcompete native species, reducing biodiversity even further. To avoid negative repercussions for aquatic ecosystems, the ecological implications of nutrient pollution, particularly eutrophication caused by excessive nutrient discharge, should be properly regulated.

Finally, the environmental impacts of algae-based fuel generation are complex, including both possible benefits and concerns. Carbon sequestration, wastewater treatment, and reduced reliance on freshwater resources all have significant environmental benefits. However, to solve challenges such as habitat degradation, invasive species, and nutrient contamination, vigilance is essential. Responsible and sustainable practises, as well as strong environmental legislation, are required to maximise the ecological benefits of algae-based fuel production while minimising negative effects on aquatic ecosystems and biodiversity. More study and continual monitoring are required to assure the environmental sustainability of this promising technology.

## References

- Anderson DM, Glibert PM, Burkholder JM. Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. *Estuaries*,2002;25(4):704-726.
- Becker EW. Micro-algae as a source of protein. *Biotechnology Advances*,2007;25(2):207-210.
- Behera S, Singh R, Arora R, Sharma NK, Shukla M. Recent developments in microalgal biomass production with a focus on modeling and simulation: A review. *Renewable and Sustainable Energy Reviews*,2018;91:657-671.
- Benemann JR. Microalgae for biofuels and animal feeds. *Energy Procedia*,2013;37:6031-6038.
- Borowitzka MA. High-value products from microalgae—their development and commercialisation. *Journal of Applied Phycology*,2013;25(3):743-756.
- Borowitzka MA, Moheimani NR. Sustainable biofuels from algae. *Mitigation and Adaptation Strategies for Global Change*,2013;18(1):13-25.
- Carney LT, Reinsch SS, Lane PD, Solberg OD, Woods HA. Pathogens in algae: International journal of marine science and engineering,2014;4(4):155-175. MDPI.
- Chinnasamy S, Bhatnagar A, Hunt RW. Microalgae cultivation in a wastewater dominated by carpet mill effluents for biofuel applications. *Bioresource Technology*,2010;101(9):3097-3105.
- Chiu SY, Kao CY, Chen TY, Chang YB, Kuo CM, Lin, *et al.* *Bioresource Technology*,2015;184:179-189.
- D'Este M, Aro EM, Van Wageningen J, Giordano M. Growth of algae on concentrated municipal wastewater as nutrient source for biofuels production. *Biotechnology for Biofuels*,2019;12(1):218.
- Eriksson HM, Andreasson J, Stockfelt L. Factors influencing the use of on-site wastewater treatment in Sweden. *Water Science and Technology*,2002;46(1-2):75-81.
- Fábregas J, Maseda A, Domínguez A, Otero A. The cell composition of *Nannochloropsis* sp. changes under different irradiances in semicontinuous culture. *World Journal of Microbiology and Biotechnology*,2003;19(1):71-75.
- Fletcher TD, Andrieu H, Hamel P. Understanding, management and modelling of urban hydrology and its consequences for receiving waters: A state of the art. *Advances in Water Resources*,2015;51:261-279.
- González-García Y, Branney J, Pogson M. Photobioreactor design for improved energy efficiency and economy of scale. *Algal Research*,2015;10:147-156.
- Grima EM, Belarbi EH, Fernández FGA, Medina AR, Chisti Y. Recovery of microalgal biomass and metabolites: process options and economics. *Biotechnology Advances*,2003;20(7-8):491-515.
- Gupta VK, Tuohy MG. *Biofuel technologies: recent developments* Springer, Berlin Heidelberg, 2013.
- Gupta A, Shrivastav A. Potential of microalgae for wastewater treatment and biodiesel production. *Journal of Environmental Management*,2014;113:298-308.
- Hallegraeff GM. Ocean climate change, phytoplankton community responses, and harmful algal blooms: a formidable predictive challenge. *Journal of Phycology*,2010;46(2):220-235.
- Hornbuckle A, Lim RP, Conway J. Water quality and agricultural runoff: A simulation study of selected policy scenarios in the Grand Lake St. Marys watershed. *Environmental Science & Policy*,2015;50:150-162.
- Hosseini SE, Wahid MA, Aghili N. The scenario of greenhouse gases reduction in Malaysia. *Renew Sustain Energy Rev*,2013;28:400-9.
- Khan SA, Hussain RMZ, Prasad S, Banerjee UC. Prospects of biodiesel production from microalgae in India. *Renew. Sust. Energ. Rev*,2009;13:2361-2372
- Kladivko EJ, Frankenberger JR, Jaynes DB, Helmers MJ, Salas W. Cover crops in the upper Midwest. *Journal of Soil and Water Conservation*,2014;69(4):282-299.
- Kovscek AR, Cakici MD. Geologic storage of carbon dioxide and enhanced oil recovery. II. Cooptimization of storage and recovery. *Energ. Convers Manage*,2005;46:1941-1956.
- Kumar A, Ergas S, Yuan X, Sahu A, Zhang Q, Dewulf J, *et al.* Enhanced nutrient removal from wastewater

- effluent by integrating microalgal cultivation with the anaerobic digestion process. *Bioresource Technology*,2010:101(14):4128-4133.
25. Lam MK, Lee KT, Mohamed AR. Current status and challenges on microalgae-based carbon capture, *Int. J. Green. Gas Control*,2012:10:456-469.
  26. Leng L, Hu M, Sawayama S. Algicidal microorganisms and their ecology. In *Microalgae in Health and Disease Prevention*, 2015, 287-307. Academic Press.
  27. Liu J, Wu Y, Wu Z, Zhu D. A review of nitrogen removal in wastewater treatment by microalgae. *Frontiers in Environmental Science*,2017:5:5.
  28. Mara D, Pearson H. Guidelines for the safe use of wastewater and excreta in agriculture and aquaculture: measures for public health protection. World Health Organization, 1998.
  29. Mara D, Feachem R, Bradley D. Sanitation and disease: health aspects of excreta and wastewater management. World Bank Publications, 2007.
  30. Mata TM, Martins AA, Caetano NS. Microalgae for biodiesel production and other applications: a review. *Renewable and Sustainable Energy Reviews*,2010:14(1):217-232.
  31. Mendez L, Mahdy A, Lopez F, Sforza E, Vítolo M. An integrated green algal system for effective and economic wastewater treatment: From wastewater characterization to final biomass disposal. *Algal Research*,2017:24:229-237.
  32. Metcalf L, Eddy HP. *Wastewater engineering: treatment and reuse*. McGraw-Hill Education, 2013.
  33. Mobin S, Alam F. Some promising microalgal species for commercial applications: A review, *Energy Procedia*,2017:110:510-517.
  34. Mobin SMA, Alam F. "A review of microalgal biofuels, challenges and future directions", in *Application of thermo-fluid processes in energy systems: key issues and recent developments for a sustainable future*, edited by M. M. K. Khan, A. A. Chowdhury, N. M. S. Hassan (Springer Nature Singapore Pte Ltd., Singapore,), 2018, 83-108.
  35. Ometto F, Quiroga G, Toffanin A. Towards a sustainable biobased industry: Valorization of algae to produce low-molecular weight biomolecules. *Bioresource Technology*,2019:290:121720.
  36. Pittman JK, Dean AP, Osundeko O. The potential of sustainable algal biofuel production using wastewater resources. *Bioresource Technology*,2011:102(1):17-25.
  37. Pulz O, Gross W. Valuable products from biotechnology of microalgae. *Applied Microbiology and Biotechnology*,2009:65(6):635-648.
  38. Saeidi M, Eslami A, Zarei M. Industrial wastewater treatment: A review. *Journal of Environmental Chemical Engineering*,2019:7(3):103291.
  39. Salmaso N, Boscaini A, Capelli C, Cerasino L, Leoni B, Morabito G. Plankton dynamics across the freshwater, transitional and marine research regions of the Lagoon of Venice. *PLoS ONE*,2018:13(5):e0196313.
  40. Smith DR, Owens PN, Leytem AB, Warnemuende EA. The use of water quality indicators to assess the impact of land use on the spatial variability of stream water chemistry. *Water, Air, and Soil Pollution*,1999:113(1-4):331-352.
  41. Smith VH, Joye SB, Howarth RW. Eutrophication of freshwater and marine ecosystems. *Limnology and Oceanography*,2008:51(1):351-355.
  42. Smyth AR, Benke KK, Campbell BG, Lindenschmidt KE, Pomeroy CA. Landscape-scale impacts of regulation on hydrology and water quality in the Prairie Pothole Region of Western Canada. *Ecohydrology*,2016:9(5):828-843.
  43. Sørensen M, Krause-Jensen D, Valdemarsen T. Eelgrass as a bioindicator under the European Water Framework Directive. *Environmental Monitoring and Assessment*,2013:185(11):9249-9261.
  44. Stewart TW, Vondracek B, Ferrington Jr LC, Friedman JM. Impacts of land use on water quality and aquatic communities in the Minnesota River Basin. *Ecological Applications*,2018:28(5):1226-1241.
  45. Tredici MR. Photobiology of microalgae mass cultures: understanding the tools for the next green revolution, *Biofuels*,2010:1:143-162.
  46. Volesky B. Detoxification of metal-bearing effluents: biosorption for the next century. *Hydrometallurgy*,2001:59(2-3):203-216.
  47. Xie Z, Xu X, Cai L, Yu H, Zhang M. The ecological impacts of large-scale mariculture: A case study of nutrient dynamics in Xiangshan Bay, China. *Environmental Pollution*,2019:255:113274.
  48. Yusuf C. Biodiesel from microalgae. *Biotechnology*,2007:25:294-306.
  49. Zhao H, Yu J, He J, Cao W, Li J, Tang J. Advances in remote sensing of water quality. *Environmental Science and Pollution Research*,2017:24(3):1905-1926.