Study on Utilizing Algae for Environmental Remediation

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論　文　内　容　の　要　旨

An increase in atmospheric carbon dioxide levels can result in catastrophic natural disasters, including floods, droughts, cyclones, sea level rise, ecological imbalance, and human diseases, which are alarming for mankind's survival. According to National Oceanic and Atmospheric Administration, humankind must reduce its overall carbon dioxide emissions by at least 80% by 2050. Existing carbon capture and storage techniques are exceedingly expensive, and such cutting-edge technology is not accessible in developing nations. Therefore, it is essential for scientists to develop an effective and affordable technology to reduce carbon emissions. Biological CO_2 fixation can be considered one of the prominent futuristic technologies as it is affordable and environmentally viable. Algae can be used as a food, nutraceuticals for humans, ingredients for fish and animal feed, and as sorbents for heavy metal remediation. Additionally, algae are utilized for producing innovative ingredients for biofuel, cosmetics, healthcare, and therapeutic products, which are entirely biodegradable. After biodiesel extraction, the residual biomass can be utilized in heavy metal, such as arsenic, chromium, lead, and others removal. Besides having considerable advantages in the application area, algae production requires nominal land areas compared to conventional agriculture. The algae cultivation system largely depends on available technology, cost, quality of biomass, weather, hygienic factors, and bio-based products. It is possible to control the environmental parameters during the cultivation period in the closed photo-bioreactor, such as temperature, pH, light, CO_2 concentrations, and other environmental factors, to obtain higher biomass yields. Regarding the biological CO_2 fixations, this research focuses on utilizing captured CO_2 as a growth enhancer for algae cultivation. The present thesis also addresses the application of dried algal biomass in removing heavy metals from contaminated water. This thesis comprises seven self-explanatory chapters.

Chapter 1 describes a general introduction that provides the fundamental ideas regarding algae cultivation, environmental parameter effects, and applications of algae on removal technology. Besides, it includes the motivation behind this work and the aims, objectives, and organization of the thesis.

In **Chapter 2**, a survey was conducted to identify the demand for algae-based supplement products in Bangladesh. For this reason, the contingent valuation method with a bidding game approach was employed to find willingness to pay and willingness to accept algae-based products. The age group and educational level had the greatest impact on people's awareness of spirulina use. Finally, this chapter presents that public attitudes towards new food products would be possible if manufacturers developed affordable food products.

Chapter 3 analyzed several widely used kinetic models to determine algae growth. The substrate-based kinetic models, such as Monod, Haldane, Aiba, Hinshelwood, Yano and Koga, Teissier, Andrews, and Webb model, was used to analyze the algae growth. Based on the existing models' shortcomings, we proposed a modified model which shows better results than the studied models.

Chapter 4 elaborates on the algae cultivation mechanism employing the high-density gas dissolution technique. Using this system, captured CO_2 can be dissolved into the water without the risk of exposing this greenhouse gas to the air. Response surface methodology was applied to assess the potential contributions of cultivation time, irradiance light, and CO_2 concentration during the cultivation process for *Agardhiella subulata*. Furthermore, their interaction effects were evaluated during the cultivation period. Algae cultivation was the highest at 7 days, 418 μmol/m^2/s light intensity, and 20 mg/l CO_2 concentration.

Chapter 5 presents the growth rate of *Caulerpa lentillifera*, which is found to be almost double in CO_2-enriched seawater at 20 mg/l compared to natural seawater. The modified Gompertz model shows a high R^2 value of 0.9974, and a low residual sum of squares value of 0.00198, indicating the best fit with experimental data in this study. It was confirmed that CO_2-enriched seawater has a significant effect on promoting the growth of *Caulerpa lentillifera* and its high economic superiority. Increasing algae production employing CO_2 will help to promote a sustainable environment and contribute to sustainable development goals.

Dry *Chlorella vulgaris* (CV) biomass and nano zero valent iron (NZVI) composite was used for arsenic removal via an adsorption technique presented in **Chapter 6**. Batch tests were carried out on different parameters such as temperatures, pH, adsorbent ratio, and As(V) concentration. In case of the arsenic removal, 1.5 g/l CV/NZVI composite eliminates approximately 28.8 mg/g of 40 mg/l initial As(V) concentration. The kinetic study demonstrated that the removal of As(V) by CV/NZVI composite was adequately expressed by the pseudo-first-order model, which had high R^2 values of 0.99. This composite exhibits a high removal efficiency compared to the previously reported studies. The composite CV/NZVI reactive functioning towards As(V) removal in groundwater revealed the enormous possibility of using this composite in actual water treatment plants. This study recommends that one could employ the CV/NZVI composite as a reactive permeable barrier for groundwater remediation, which is an efficient material for treating As(V).

The main findings of the study, as well as the author's originality and contribution, are summarized in **Chapter 7**, which also suggests some recommendations for future improvement.