Biofuel and bioremediation potential of microalgae

Ramachandra T V*[1, 2] and Saranya Gunasekaran[1, 2]
[1]Energy & Wetland Research Group, Centre for Ecological Sciences,
[2]Centre for Sustainable Technologies,
Indian Institute of Science, Bangalore – 560012.
*Corresponding Author: tvr@iisc.ac.in, ORCID: 0000-0001-5528-1565

Escalating fuel prices, rising environmental concerns and dwindling stocks of fossil fuel have necessitated the exploration of viable alternative feedstocks. Biofuel from microalgae has been showing the prospects of a viable alternative to the conventional fossil fuels. This article assesses the prospects of biofuel from diatom consortia[1] and also the bioremediation[2] potential to treat the nutrient-rich aquaculture wastewater.

Wastewater generated in domestic, industrial and agricultural sectors comprises mainly of 99% water and 1% solid (both organic and inorganic) constituents. The characteristics of wastewater especially the proportion and properties of solid constituents alter depending on its sources of origin. For example, in domestic wastewaters, organic constituents include carbohydrates, fats, lignin, synthetic detergents, various aliphatic and aromatic chemical compounds from household pharmaceutical waste disposal [Ramachandra et. al. (2013)]. On the other hand, wastewater generated in aquaculture from shrimp farms are characterized by large proportions of total suspended solids (TSS) which are mostly of inorganic origin due to eroded material from pond floor and embankments in addition to dissolved nutrients, particularly nitrogen from un-utilized protein feeds, phosphates and organic carbon from phytoplankton and detritus[3]. In addition to nutrients, shrimp wastewater also contains soluble and insoluble biochemical compounds such as pesticides, disinfectants, antibiotics, immunostimulants, vitamins and feed additives. This can cause substantial sediment loading and eutrophication[4] when discharged to the surrounding water bodies as partially treated or untreated. India has the distinction of having higher aquaculture production next to China, which results in the humungous generation of wastewater and its subsequent release to the surrounding coastlines. India's coastal line with a stretch

---

[1] Diatom consortia is an association of several microscopic unicellular algae of a particular category called the phylum Bacillariophyta, occurring in marine or fresh water in single or in colonies. In such algae, each cell has a cell wall made of two halves and impregnated with silica.

[2] Bioremediation is a process that uses mainly microorganisms, plants, or microbial or plant enzymes to detoxify contaminants in the soil and other environments.

[3] Deritus is organic matter produced by the decomposition of organisms.

[4] Eutrophication refers to excessive richness of nutrients in a lake or other body of water, frequently due to run-off from the land, which causes a dense growth of plant life.

of 7,517 km has land-based aquaculture in estuarine brackish water regions contributing significantly to the global production of fishes, molluscans and crustacean. Among aquacultures, shrimp aquaculture is becoming the fastest growing economic activity in Asia-pacific regions with India becoming a leading exporter of commercial farmed shrimps. India’s shrimp production is constantly increasing since 2011 with an estimated annual production of 0.48 MMT (Million Metric Ton) in 2018. Fig. 1 depicts the spatial extent of aquaculture ponds, shrimp productivity and an estimate of wastewater generated across the Indian States.

Microalgae help in bioremediation of wastewaters through bio-assimilation of nutrients into numerous organic molecules either fixed autotrophically or heterotrophically [Mahapatra et. al. (2014), Ramachandra et. al. (2013)]. The autotrophic mechanism involves the utilization of CO_2 from the atmosphere and light energy from the sun during photosynthesis for biomass production in the form of carbohydrates and lipids. Mostly inorganic mineral constituents (Nitrogen, Phosphorous and Silica) are utilized in autotrophy, whereas in the heterotrophic mechanism, organic carbon is directly consumed by algae for nutrition, replacing the necessity of light energy.

Microalgae - diatoms are known to possess promising capabilities including its predominant presence in estuarine and continental shelves, accumulate 8% more lipid content (% as of dry cell weight) than green microalgae during its exponential growth phase.

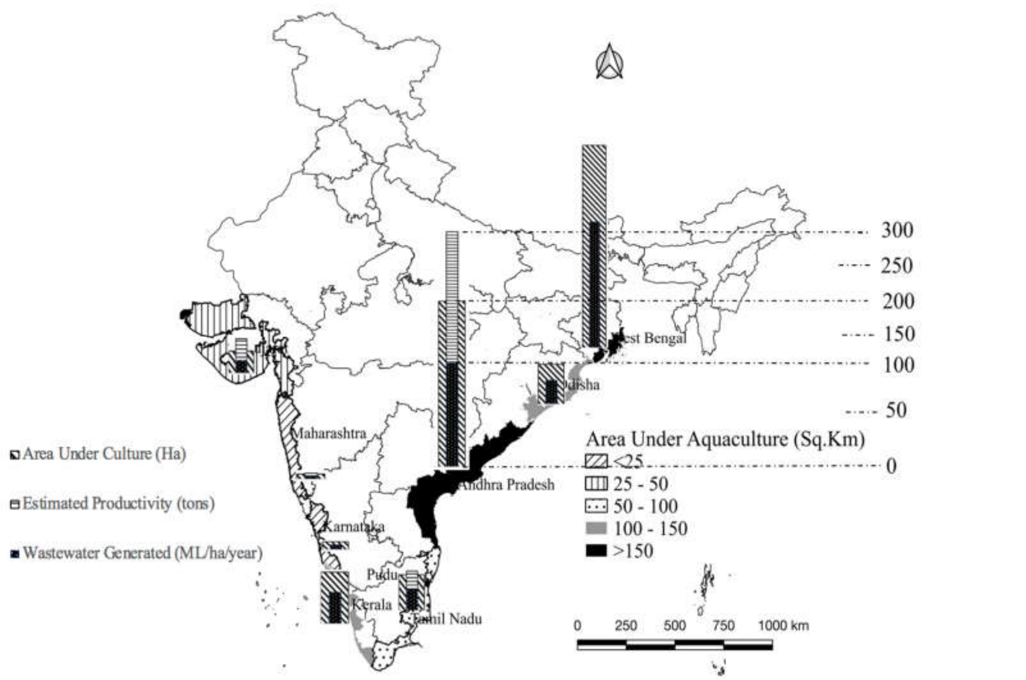

Fig. 1 State-wise Aquaculture production & its associated wastewater generation

Estimates indicate that about 343.53 ha. of land is under shrimp cultivation in Karnataka State, India with an estimated productivity of 3.14 Mt/ha/yr. Uttara Kannada district with a total area of 218.06

ha. under shrimp cultivation, constitutes one of the major producers of shrimps. Uttara Kannada has the highest share (4200 ha.) of brackish water formations, out of which 1450 ha. of land are gazni lands (brackish water embayment). The local fisherfolks practice traditional shrimp farming in these gazni lands. The traditional method of shrimp cultivation is being practised extensively with no external feed inputs for shrimps' growth and such practice lowers environmental loadings and nutrient enrichment in the receiving water bodies. However, large-scale commercial activities involving semi-intensive and intensive types of shrimp farming where selective and higher seed stocking[5] is practised, which generates higher quantum of wastewater rich in total suspended solids (TSS) and dissolved nutrients such as total Nitrogen (TN), total phosphorus (TP) and Total Organic Carbon (TOC). Also, intensive shrimp farming has inherent long-term management problems such as loss of coastal habitats and agricultural lands due to salinization, culture stock losses due to disease outbreaks, slow growth of shrimp fry and other socio-economic issues. This necessitates appropriate low-cost mitigation strategies to minimise organic pollution due to commercial shrimp production units. Thus, incorporation of the decentralised microalgal system near shrimp cultivation sites would aid in remediation of organic nutrients, through bio-assimilation as well as biofuel production from the microalgal consortium. In this regard, lipid productivity potential of marine microalgae needs to be understood and the present research focussed on growing microalgal consortia, predominantly composed of benthic diatoms[6] using aquaculture wastewater under laboratory observations.

Microalgae (benthic diatoms) were collected from sediments of a mangrove-rich brackish water region (14°31'9.55"N, 74°23'7.53"E) of the Aganashini estuary. Fig. 2 shows the light micrographic images of the diatoms that were present in the consortia.

Diatom consortium naturally occurring in the estuarine ecosystem were monitored in the laboratory with aquaculture wastewater in-order to understand the technical feasibility of the large-scale microalgae production. The biomass productivities of microalgae under diverse nutrient conditions varied between 32.3 – 41.6 mg $L^{-1}day^{-1}$, with lipid content ranging between 24 to 42% of dry cell weight. Bioremediation potential is evident from the mean nutrient removal efficiencies of 89 % and 90 % for total nitrogen (TN) and total phosphorus (TP) respectively. Further analysis[7] provided insights to the treatment of aquaculture wastewater through microalgal biomass, extent of lipid accumlation and

[5] Seed stocking is the selection of good quality seed for stocking into a pond and this is the first important step of the shrimp grow-out management.

[6] Such diatoms are the dominating group of benthic algae, and therefore play an important role as primary producers, especially in running water

[7] Flow cytometric analysis of microalgal cells depicted the real-time accumulation of neutral lipids in-vivo during different phases of cell growth. Fatty acid profiling through GC-MS showed higher percentages of saturated and monounsaturated fatty acids of C16 and C18 carbon chains.

also the optimal day for harvest of microalgae. Moreover, the higher composition of mono-unsaturated and saturated fatty acids highlights the scope for biodiesel.

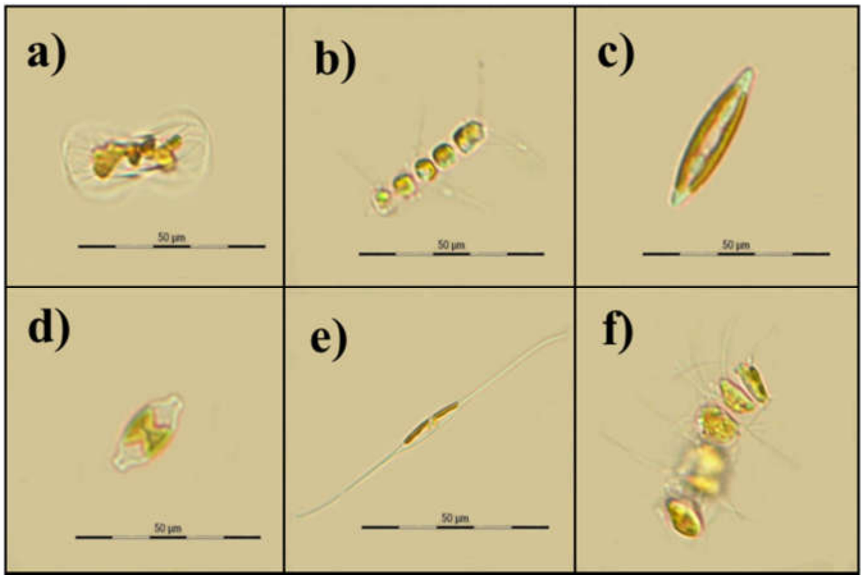

Fig. 2 Light Micrographic images of diatoms present in the Culture Consortium

Conclusion

The removal of nutrients such as TN (~89%) and TP (~90 %) and higher lipid content in algae, highlights the bioremediation potential with biofuel prospects of the microalgal consortia grown in aquaculture wastewater. India has the distinction of having higher aquaculture production next to China, which results in the humungous generation of wastewater and decentralized diatom based microalgae treatment system will help in treating wastewater as well as aid in ensuring energy security through biofuel.

References

1 Ramachandra T V., Durga Madhab M, Shilpi S, et al. Algal biofuel from urban wastewater in India: Scope and challenges. Renewable and Sustainable Energy Reviews [Internet]. 2013 [cited 2018 Apr 23];21:767–777. Available from: https://www.sciencedirect.com/science/article/pii/S1364032112007320.

2 Mahapatra DM, Chanakya HN, Ramachandra T V. Bioremediation and lipid synthesis through mixotrophic algal consortia in municipal wastewater. Bioresource Technology [Internet]. 2014;168:142–150. Available from: http://dx.doi.org/10.1016/j.biortech.2014.03.130.

3 Ramachandra T V., Durga Madhab M, Shilpi S, et al. Algal biofuel from urban wastewater in India: Scope and challenges. Renewable and Sustainable Energy Reviews. 2013;21:767–777.