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On Earth Harmony: Algae Crafting Environment Revival

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Abstract

In the intricate dance of nature, algae emerge not just as the silent architects of vibrant underwater realms, but as the unsung heroes with the power to breathe life into the natural world. In this comprehensive analysis we go through how algae jack into— carbon's void by sequestering carbon of CO_2 using photosynthesis and mitigates greenhouse emissions, purifies tainted waters by using wastes from wastewater like nutrients, sparks a green revolution as it produces biofuels and being used as food for nutrient enrichment as well as monitors environment as biosensors, thus concluding into algae's ability to transcending conventional boundaries of environmental stewardship. The more emphasis will be on illuminating on major benefits like biofuels, carbon sequestration and wastewater treatment which might be sweet in the citrus.

Keywords: Microalgae; Application; Wastewater treatment; Carbon sequestration; biofuels.

INTRODUCTION

The environment is deteriorating and different pollution is emerging as severe problems around the globe. Thus, rendering it to fundamental concern to ecotoxicologist, environmental biologist, eco-chemists, pathologist and many other fields of research. Therefore, advanced methods redefining approaches meeting the demands of growing world; called 'green agenda'. The Algae being diverse photosynthetic group of eukaryotes diversified in many species and genera like Chlorophyta, dinoflagellates, diatoms, etc. they have emerged as valuable environmental applicators becoming the sustainable solutions across various sectors. Their ability of absorbing nutrients, in wastewater treatment, aiding water purification, forming biofuels and many more. Emerging environmental contaminants present in wastewater are drawing significant awareness as they exhibit several bad qualities such as high polarity, the ability to be bioaccumulated by aquatic organisms and resistance to biodegradation. They harm the aquatic ecosystem and human health as well. The most common contaminants include not only pharmaceuticals products but also several personal care products, perfluorinated compounds, gasoline additives, surfactants, organometallic compounds, disinfection by-products, brominated and organophosphate flame retardants, endocrine-disrupting compounds,

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nanoparticles and plasticizers (Müller *et al.,* 2007; Morin-Crini *et al.,* 2022). Algae-based technologies have demonstrated greater efficiency in removing emerging contaminants (Morin-Crini *et al.,* 2022) at bothlaboratory scales and in real wastewater.

Bioremediation is basically the use of living biological organisms in order to remove the contaminants. Algae can be used in bio-remediatingindustrial effluent including heavy metal, dye, nitrogen, phosphorus, etc. removal.

Heavy metal are the class with atomic density >4000 kg m^3 (Vardhan *et al.,* 2019). They show accumulation and thus are having non-biodegradable properties, toxicity and thus be a critical problem worldwide. A heavy metal being pollutant also causes diseases like nervous system disorder, gastrointestinal and kidney dysfunction, vascular damage, skin lesion, immune system dysfunction and cancer even at low concentrations (Edelstein *et al.,* 2018).

Heavy metals have three categories: 1) radionuclides 2) precious metals 3) toxic metals (Pavithra *et al.,* 2020; Kafil *et al.,* 2022).The heavy metals can be removed by Biosorption and bioaccumulation (Ahmed *et al.,* 2022).

- First method, bioaccumulation works by transporting metal ions across cell membrane using passive and active transport. Method occurs only in live cells.
- Second one, biosorption involves the sorption of metals onto the cell surface which will be helped by Exopolysaccharides (Ahmed *et al.,* 2022).

Applications of algae:

Throughout the last several decades, the world frugality has expanded at a dramatic pace. Extreme population expansion is a major issue, with the world's population cast to reach 8.5 billion in 2030, 9.7 billion in 2050 and 10.9 billion by 2100 (United Nations, 2019). As a consequence of the growing global population, large quantities of energy and coffers have been consumed and pollution situations are high. The necessity of anticipating and preparing for these heads has been honored and appreciated by numerous transnational associations. Promoting a "green frugality" is one similar plan. The green frugality conception was developed during the 2012 United Nations Conference on Sustainable Development in Rio de Janeiro and it's grounded on the idea that environmental protection helps both the frugality and society. The thing of this conception is to empower growers and manufacturers to produce further environmentally friendly product and consumption systems grounded on exercise and recovering for sustainable development (Loiseau *et al.,* 2016).

Fig. 1: Applications of algae Adopted from Kandasamy *et al.,* 2022

Nutrients bioremediation by algae

External and agrarian waste water contains a large quantum of nutrients like nitrogen, phosphorus and other minerals. The predominant forms in which they do in wastewater are ammonium ions, nitrite, nitrate and orthophosphate. Phosphate enters the algal cell laboriously through a symporter with H or Na ions furnishing the driving force. Algae also hydrolyze organic phosphorus composites with membrane-bound as well as free phosphatases, releasing bioavailable phosphorus that's latterly taken up by the algal cells (Bolan *et al.,* 2004). Among inorganic nitrogen sources, algae preferentially take up ammonium because of its further stoutly favorable assimilation and direct protein objectification process (Bolan *et al.,* 2004). Algae uptake ammonium by a group of membrane transporter proteins belonging to the ammonium transporter family. On the other hand, nitrate and nitrite are reduced to ammonium, by nitrate reductase and nitrite reductase, independently, for intracellular uptake, which is energy ferocious.

Removal of contaminants by algae

Algae as being able to tolerate toxic elements and require heavy metals as like zinc, molybdenum, manganese, iron, cobalt, copper and boron as trace elementsthus they can grow and metabolize whereas some like cadmium, chromium, lead, arsenic, mercury are harmful to them.

This called hormesis, is a process of requiring toxic heavy metals for growth. Precious metals Ag and Au can be recovered while removing toxic radioactive elements from water and these algae can tolerate toxicity via mechanisms like as gene regulation, heavy metal immobilization, chelation, exclusion and the production of different enzymes that decrease the toxicity of these substances. (Monteiro *et al.,* 2012; Tripathi and Poluri, 2021; Manikandan *et al.,* 2022)

Heavy metal control by algae majorly follows biosorption and bioaccumulation, it can form organometallic compound with heavy metals in cytoplasm and separating vacuoles. The biosorption ismetal ion binding to dead or inactive algal cells via different interaction like electrostatic, chelation, ionic, etc. (Srimongkol *et al.,* 2022).

Instead bioaccumulation involve live algae where first the semi biosorption takes place with metal ion binding functional groups like -OH, -COOH, amine, etc. on wall of cell. Then second phase, intracellular uptake happens, ingesting these toxic elements playing crucial role in detoxification. (Srimongkol *et al.,* 2022).

Some studies show dead algae being better in *wastewater* treatment as for live algae show restricted sorption due to the live cell poisoning; also live cells have complex intracellular mechanism for the uptake of contaminant which makes absorption complex. On the other hand dead ones will act as assemblers of polymers which absorbs metals at extracellular level. (Salam, 2019).

Algal species from family *Phaeophyceae* in which alginate serves mainly for heavy metal binding which directs the influence on biosorption. A weird matter of fact is some contaminant specifically boost rates of other contaminants; for example, sulfamethazine removal gets increase by presence of sulfamethoxazole (Xiong, 2019). Co-metabolism reported in *Chlamydomonas Mexicana* removes ciprofloxacin after adding sodium acetate, here breakdown via enzyme takes place (Xiong, 2019). Temperature effects as higher temperature increases rate of entire process (Vijayaraghavan and Yun, 2007).

Studies show that by product formed can may be proven more toxic than primary compound, one such case is textile water remediation using *Oscilllatoria tenuis, Chlorella pyrenoidosa* and *Chlorella vulgariscan* degrade azo dyes into simple aromatic amines being carcinogenic and persistent (Fazal, 2018). Thus, before using algae systems, the study should be made for effects of environmental factors on monitoring and growth of algae for successful application.

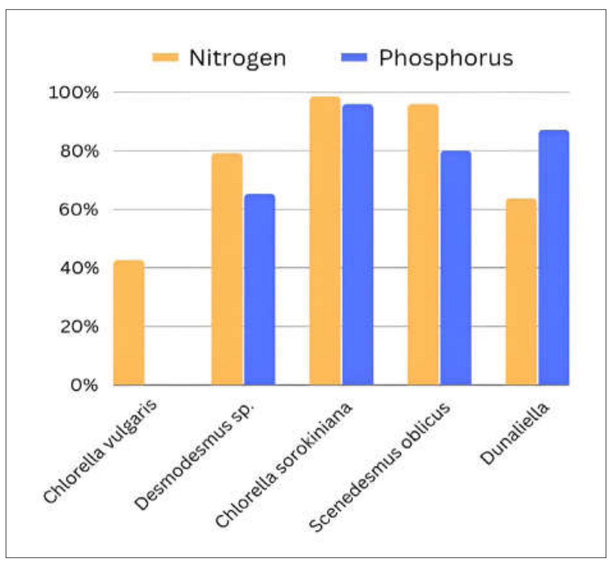

Fig. 2: Percentage removal of Nitrogen and phosphorus by different algal species

Pharmaceutical contaminants can be removed based on their physiological properties using microalgae. A study by De Godos *et al.,* 2012, showed ability of *Chlorella vulgaris* for removing more than 50% tetracycline via adsorption as interaction established between positively charged molecules on cell surface. Not only this but also florfenicol, trimethoprim, sulfamethoxazole and carbamazepine be bioaccumulated by *Chlorella sp*. (Song *et al.,* 2019). An algae *Scedesmus dimorphus* biodegrades 85% of 17a-estradiol in about 7days (Zhang *et al.,* 2014). The biodegradability is determined by how complex structured the compound is, *i.e.* more complex the substrate then less efficiency of degradability is seen and vice versa.

Now when studied for domestic effluent, (Wang *et al.* 2010) reported that sewage sludge (nutrient rich) cultivation of microalgae was more convenient and better than primary and secondary treated wastewater when parameters like COD, PO4-P, NO3-N and NH4-N.Zheng *et al.,* 2018, mixed piggery wastewater with brewery wastewater for determining optimal C/N ratio as to know nutrient Removal and microalgal growth; at an optimum C/N ratio of 7.9, removal efficiency of all the above mentioned parameters reached 93%, 90%, 96% and 100%.

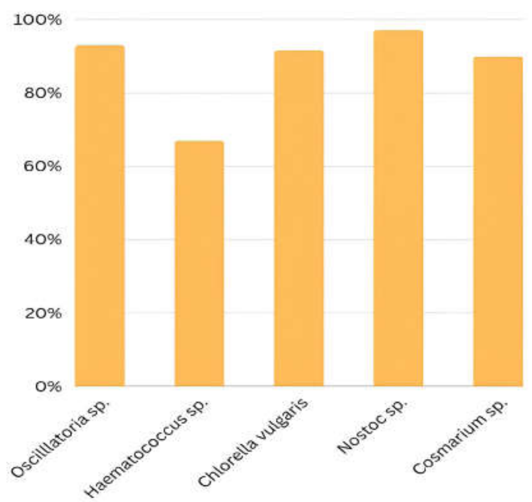

Fig 3: Percentage removal of dye using different algal species

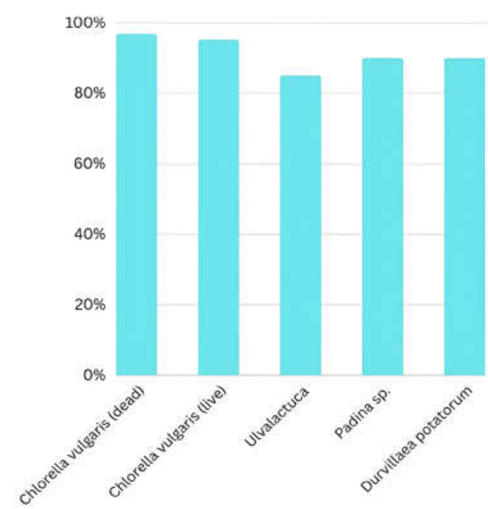

Fig 4: Percentage removal of Cadmium Data Adopted from Bilal *et. al*, 2018

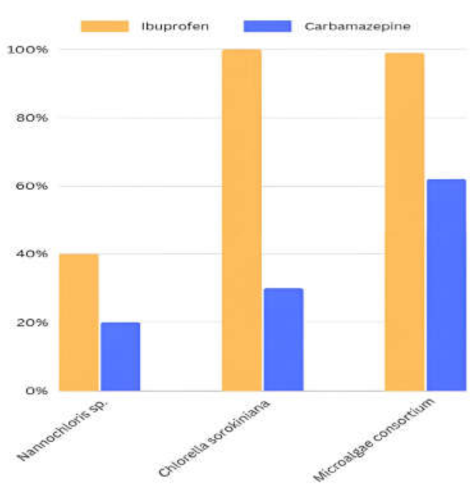

Fig 5: Percentage removal of Ibuprofen and Carbamazepine. Data Adopted from Abdelfattah *et al.,* 2023

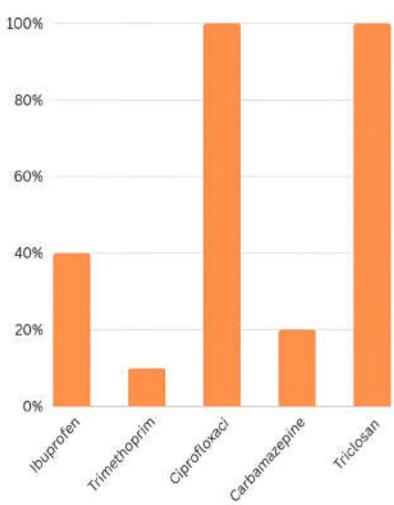

Fig 6: Percentage removal of different pharmaceutical contaminants by *Nannochloris* sp. Data Adopted from Abdelfattah *et al.,* 2023

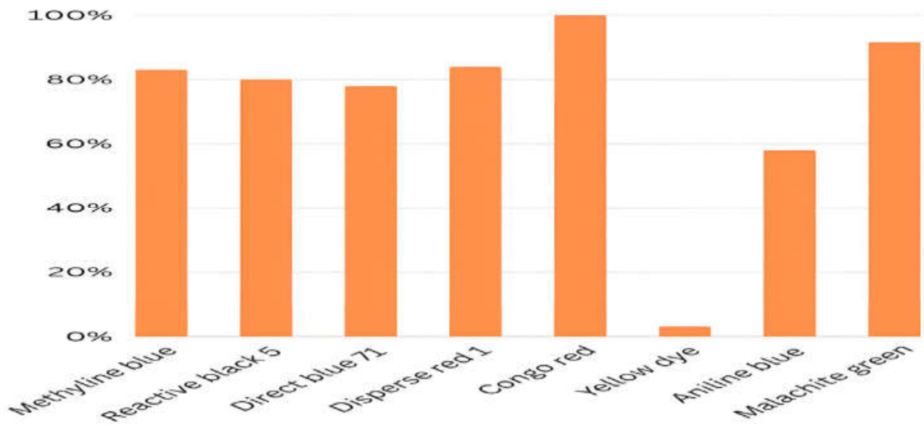

Fig 7: Percentage removal of different dyes by Chlorella sp. Data Adopted from Abdel Fattah *et al.*, 2023

Carbon sequestration

As said by IEA in 2021 that CO_2 amount is to be rebound and increase by 4.8% as 2019 reaches peaks of fossil fuel rebound with increasing demand, which pose the problem of increased green house pollution. Algae being magically active creatures can utilize this CO_2 via photosynthesis and recycle them in form of bioenergy which makes using microalgae a sustainable and environment friendly way (Brilman *et al.,* 2013).

CO_2 assimilation by photosynthesis involves both light dependent and light independent reactions; moreover this CO_2 is converted to carbohydrate precursors and biomass which later synthesizes major biomolecules like lipids, proteins and nucleic acids (Zeng *et al.,* 2011; Gg and Liu, 2021).

A report stated, cost of manufacturing *Chlorella* Biomass is around $4.87 per kg having consumed 0.96kWh per kg of energy (Valdovinos-García *et al.,* 2020).Moreover around 2.2 kilotons of CO_2/ year is sequestered using 4000m^3 microalgae growth in pond systems when natural sunlight is available (Stewart and Hessami, 2005).

According to some other studies, algae might reduce CO_2 emissions by 50% (Stepan *et al.,* 2002).

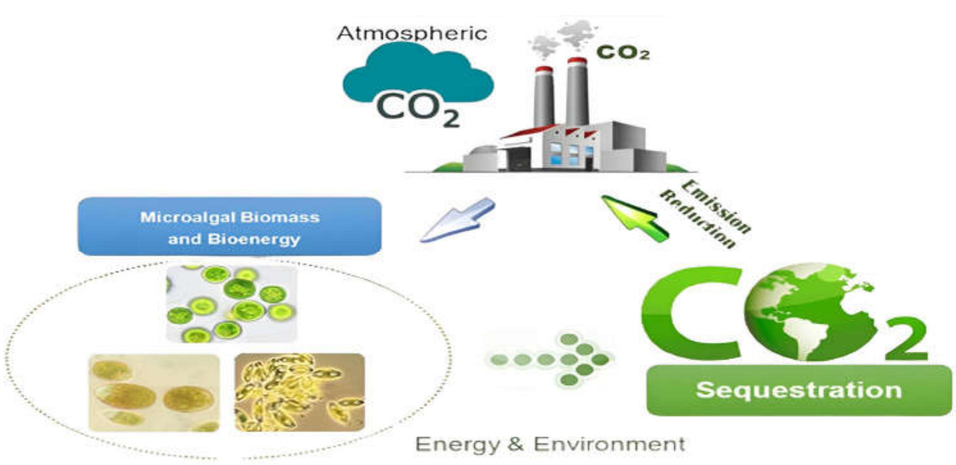

Fig 8: Represents Co_2 sequestration process Adopted from Zhaom *et al.*, 2020

Biofuels

Biofuels are the fuels coming to rescue in the form of renewable energy as the threat of losing these petroleum basedfossil fuels we are using now. Biofuels include ethanol, biodiesel, biohydrogen.

Microalgae have a capacity as a patron similar to that of a land factory, which has been critical to mortal survival for a long time in history considering terms of significant sources of food, drug, erecting accoutrements and energy force. Different photosynthetic unicellular microalgae are arising as new sources of renewable energy that can fulfill the demands of the conditioning. Microalgae lipids can be employed as a raw material for biodiesel conflation and remaining biomass rich in carbohydrates can be used to produce bioethanol or biogas. They generally accumulate lipids between 20 - 50% of their dry weight Yet Some species can be as high as 80% under certain condition (Chisti, 2007). These neutral lipids, substantially in the form of triacylglycerols (mark up to 90 – 95%), which can be converted to adipose acid methyl esters (FAMEs) and converted biodiesel. Algae have advantages over first generation biofuels made from sugar, bounce and vegetable oil because of their high growth rates and productivity, capability to grow on a non-arable land using wastewater, capability to use water pollutants and CO_2 and capability to produce a variety of high-value natural product of biodiesel from microalgae comprises two different way: 1) lipid birth from microalgal cells and 2) transesterification of lipids using alcohol and a catalyst (Mondal *et al.,* 2017). In a primary study of biomass product and ammonium junking in *Synechococcus sp*. VDW (accession number MH393765) insulated from natural seawater in Thailand (Tinpranee*et al.,* 2018), we discovered that at optimum conditions (original pH7.4, inoculum size of 0.17 (OD730) and ammonium of 10.5 mg L −1), maximum ammonium junking and biomass productivity were 95 and 34 mg L−1 d−1, independently. A review study by Pancha *et al.,* 2019, showed colorful microalgae lipid content cultivated in colorful wastewater ranging from 18–79% w/w of biomass. Meanwhile, Chinnasamy *et al.* 2010) set up that > 96% nutrient in treated wastewater containing 85–90% carpet assiduity backwaters with 10–15% external sewage which could be removed by a range of native algal isolates. Biomass product eventuality and lipid content of 92–17.8 tons/h/time and 6.82%, independently. Biohydrogen product from microalgae can take place through in different routes but generally involves turmoil biohydrogen product (e.g., dark turmoil biohydrogen product, print turmoil biohydrogen product and print-dark combined turmoil biohydrogen product) and photosynthesis biohydrogen product (e.g., direct natural photolysis biohydrogen product, circular natural photolysis biohydrogen product) (Wang *et al.,* 2021). Batista *et al.,* 2015, reported that can grow in civic wastewater and also the biomass can be converted into biohydrogen through dark turmoil by *Enterobacter aerogenes* producing 56.8 ml H2 per gvs (Ruiz- Marin *et al.,* 2020)

Table 1: Percentage of Co2 sequestered by different algal species

Algal species	% Co2 sequestered
Cyamodium caldarium	100%
Scenedesmus sp.	80%
Cjalorococcum littorale	60%
Euglena gracilis	50%
Eudorina spp.	20%
Nannochaloris sp.	18%
Tetraselmis sp.	15%

Data Adopted from Sanyal *et al.,* 2019

The Biogas is the end product of anaerobic digestion, Generally, anaerobic digestion is conducted by two processes: 1) simple sugar is instigated by fermentative bacteria and converted into alcohols through anaerobic condensation and 2) metanogenic microorganisms use these composites and synthesize biomethane (Danquah *et al.,* 2011; Choudhary *et al.,* 2016) revealed that native colleges PA6 has good nutrient junking capability from pastoral wastewater with a theoretical methane eventuality of over to 0.79 m 3VS per kg. Kinnunen and Rintala, 2016, showed that the biomethane eventuality of *C. Vulgaris* and mixed culture of native algae species (dominating by *Scenedesmussp*.) varied between 154 and 252 L VS per kg of methanol. Depending on culture media including synthetic medium, wastewater (castrated andnon-sterilized) and digestate from anaerobic digestion of pulp and paper biosludge (castrated and non-sterilized).

CONCLUSION

Algae as a boon can thus be used to clear up the environment by mitigating CO2, reduce heavy metals by adsorption, clearing wastewater and still many others like making biofuels and being the green gold of earth.

Conflict of Interest

There are no conflicts to declare

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