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Mitigation of Global Warming Through Biological Carbon Sequestration Using Micro Algae

Avinash D Patil[1], Nandkishor Patil[2]

[1]M.Sc. Agriculture (Agricultural Microbiology), Kalaburgi- 585102, India

[2]MBA, PG Diploma Clinical Research, Kalaburgi- 585102, India

Abstract: ***The world has been threatened due to the ongoing global warming and climate change due to the bulk discharge of anthropogenic green house gases into the atmosphere through the combustion of fossil fuels, automobile exhaust gases, flue gas from the thermal power plant and other industries and forest fire caused by the natural and manmade factors. Combating the global warming and climate change by sequestering carbon through micro algae has now become the matter of great interest and a ray of hope. Micro algae utilizes carbon in the presence of sunlight to undergo photosynthesis and accumulate huge biomass in short period of time compared to terrestrial vegetation along with yielding diverse byproducts of domestic and industrial importance. Utilizing micro algae efficiently for carbon sequestration would be a mile stone towards an environmental ethics which could bond a better relationship between the man and environment in a sustainable way.***

Keywords: Carbon sequestration, global warming, micro algae, chlorophyll and photosynthesis.

1. Introduction

Global warming is regarded as a serious threat caused by the emission of green house gases. CO_2 acts as a principle green house gas produced as a result of natural and artificial phenomenon. After the industrial revolution, release of CO2 in to the atmosphere has been increased multifold as result of burning of fossil fuels and automobile exhaust. The average concentration of CO_2 increased from 315 ppm in 1960 to 380 ppm in 2007 (1). Annual anthropogenic emissions of CO_2 are estimated to be 2×10^{10} tons, this emission of green house gas is mainly attributed to increased combustion of fossil fuels. Typically, flue gas compositions with different fuel sources are approximately 10% (2). Presence of CO_2 in flue gas to the tune of 20% has been measured when coal is burned (3). The process of capture and long-term storage of atmospheric carbon dioxide (CO_2) is called Carbon sequestration (4). Several methods have been proposed to reduce the load of atmospheric CO_2 concentration, such as oceanic sequestration through oceanic injection, terrestrial sequestration, establishing fast growing vegetation and chemical methods such as cryogenic fractionation, absorption, adsorption, and membrane separation but they are less energy efficient with respect to economic perspective, time consuming and laborious. Of the several methods proposed for the carbon sequestration, micro algal carbon sequestration is believed to be more versatile (5). Microalgae uses sunlight and carbon dioxide to form biofuel, food, feed and several high-value bioactive compounds (6, 7, 8 and 9). The micro algae also known to have bioremediation potentials (10, 11 and 12) and also known to fix atmospheric nitrogen symbiotically (13). Micro algae also acts a pool of several byproducts, such as methane produced by anaerobic decomposition of algae, biodiesel and several other products of an industrial importance (14), biodiesel is derived from microalgal cells (15 and 16) and photobiologically produced biohydrogen (17) and as a source of fuel (18 and 19). Production of fuel using micro algae has now gained much momentum due to increased fossils fuel prices and effect of global warming and climate change (20).

2. Defining the Algae

Algae are the large and diverse group of simple phototrophic unicellular to multicellular organisms that utilize CO_2 during photosynthesis using green colored chlorophyll pigment (Fig 1 and 2) to produce carbohydrates, proteins, lipids, vitamins, and several byproducts (21).

Figure 1: Green algae grown on moist floor (Raichur, Karnataka)

These occur in the variety of natural aquatic and moist terrestrial habitat exhibiting the great range of diversity among them. Algae have been broadly classified in to two types based on their size into micro algae (less than 2 mm in diameter) and macro algae (are macroscopic). All the algae differs with each other with respect to colour, pigmentation, biochemical composition, nature of byproducts, photosynthetic efficiency, preferential growth medium, temperature, pH and light intensity *etc*., (22).

Different algal species so far been isolated from marine and fresh water viz., *Anabaena cylindrical, Ankistrodesmus* sp. *Botryococcus braunii, Chaetoceros muelleri, Chaetoceros calcitrans, Chlamydomonas rheinhardii., Chlorella emersonii, Chlorella protothecoides, Chlorella sorokiniana, Chlorella vulgaris, Chlorella* sp.,

Figure 2: Algae exhibiting green coloration due to the presence of chlorophyll (Raichur, Karnataka)

Crypthecodinium cohnii, Dunaliella salina, Dunaliella primolecta, Dunaliella tertiolecta, Dunaliella sp., *Ellipsoidion* sp., *Euglena gracilis, Haematococcus pluvialis, Isochrysis galbana, Isochrysis* sp., *Monodus subterraneus, Monallanthus salina, Nannochloris* sp., *Nannochloropsis oculata., Nannochloropsis* sp., *Neochloris oleoabundans, Nitzschia* sp., *Oocystis pusilla, Pavlova salina, Pavlova lutheri, Phaeodactylum tricornutum, Porphyridium cruentum, Prymnesium parvum., Scenedesmus obliquus, Scenedesmus quadricauda, Scenedesmus* sp., *Scenedesmus dimorphus., Scenedesmus obliquus., Skeletonema sp., Skeletonema costatum, Spirulina platensis, Spirulina maxima, Synechoccus* sp. *Thalassiosira pseudonana, Tetraselmis suecica, Tetraselmis* sp. (23, 24, 25 and 26) are known to sequester carbon.

Culturing the Micro Algae

A micro algae grows in all the places which ensure sufficient supply of moisture, light, temperature, nutrients. Naturally micro algae grows in the places such as open ponds, pools, ditches, reservoirs, lakes, lagoons, moist and damp walls and soil *etc*., and grows by sequestering carbon dioxide (27) but believed to be less productive than photo-bioreactor, due to limitations with respect flexibility of temperature, light, nutrients, pH *etc*., (28 and 29). Micro algae grows abundantly in the flooded water after the rainfall, flowing domestic water drainage channels (Fig 3) and results in the green coloration of water.

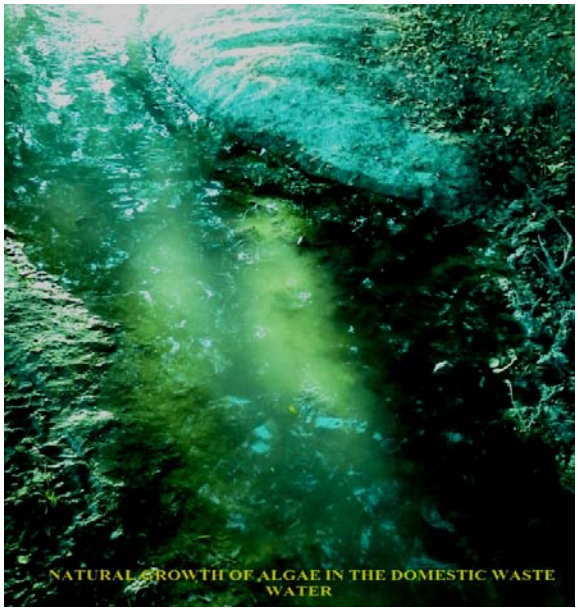

Figure 3: Natural growth of algae in domestic waste water (Raichur, Karnataka)

3. Structures Used for Growing Micro Algae

There are two methods which are most commonly used for the carbon dioxide sequestration using micro algae, are open pond system and closed photo bioreactor.

3.1 Open Ponds

This is the most simple and easy to construct and operate, as the micro algae growing in the ponds utilizes naturally available atmospheric carbon dioxide and sunlight for sequestering carbon but the productivity of the micro algae solely depends upon the diurnal and seasonal fluctuation of solar energy, CO_2 concentration of prevailing air and nutrient content of the water (30, 31and 29).

The depth of water in the range of 0.2- 0.3 m is most preferable for optimum algal growth. Uniform availability of the nutrients is ensured by using paddle wheels and guided by baffles in recirculation channels (32 and 33), which also aid in gaseous exchange. The greatest limitations of this system is large area covered due to shallow water, fluctuation in the temperature, pH and possible contamination and mutation of micro algal cells (22), less productivity and higher cost involved in harvesting of the cells (34, 35 and 36).

3.2 Closed photo-bioreactor

In this system, micro algal cultures are maintained inside the enclosed system without being in contact with the external environment. This system ensures easy maintenance, greater regulation over temperature, moisture and nutrients mixture, fewer chances of contamination, better productivity and harvest within the shortest possible time and occupies less space compared to open pond system (37, 38, 39, 40, 41 and 42). There are different types of photo bioreactors do exists such as stirred photo bioreactors, tubular photo bioreactor, flat plate photo bioreactor, hallow membrane photo bioreactor *etc*., (43, 44 and 45).

The productivity of photo bioreactors, growth characteristics and metabolic activity associated with the micro algae such as carbon sequestration, antialgal, antibacterial, antifungal and antiviral activity varies from time to time, depending upon the factors such as light, temperature, oxygen concentration, carbon dioxide, pH, incubation period of the medium and nutrients requirement (46).

3.2.1. Light

Closed bioreactor can be set upped in such a way that micro algae present in the closed bioreactor can utilize both the natural sun light emitted by the sun as well as artificial illuminated light (47 and 48). Previously good algal productivity has been reported at the light intensity of 4000 µ mol m^{-2} s^{-1}(49). The productivity of micro algae depends on the ratio of the light to dark (50 and 51).

3.2.2. Temperature

Temperature is the most crucial factor for the growth of the micro algae. Majority of the cellular and enzymatic and other biochemical activity proceeds smoothly at the optimum temperature of 15-26°C. Higher temperature elevates the algal productivity up to a limit above which there is a marked depletion in the algal growth is witnessed (52 and 48). The similar report of decreased algal growth was noticed at 7 °C. The maximum cell density was reported at 23 °C (53, 54 and 55).

3.2.3. Oxygen concentration

Oxygen gets mixed into the medium naturally as a byproduct of algal photosynthesis. Accumulation of oxygen in the medium bears the negative effect on algal growth and this condition could be avoided by using degasser or bubbling exhaust gas (54, 56 and 57).

3.2.4. Carbon dioxide

It is the important ingredient for the algal growth required during photosynthesis and is the essence of atmospheric carbon sequestration to prevent the global warming and climate change (58 and 59). The primary and secondary metabolism solely depends on the carbon content of the medium. Flue gas (approx. 13 per cent CO_2) generated by the burning of fossil fuel from the thermal power plant acts as an important source of carbon dioxide for the closed bioreactor. Bubbling of CO_2 enriched air from the bottom of the bioreactor is the most common method to add carbon into the growth medium (60).

3.2.5. pH of the medium

Optimum growth of micro algae in the growth medium is witnessed at the neutral pH. However, pumping of CO_2 enriched air into the medium make the medium acidic due to the formation of carbonic acid but there is greater algal biomass is noticed due to the utilization of carbon by algae for photosynthesis (61). Thus, there is an increase in the pH and decrease in the acidity of the growth medium is noticed after carbon being up taken by the algae (49 and 62).

3.2.6. Nutrients requirement

Carbon, nitrogen and phosphorus are the most essential nutrients required for the production of algal biomass. Ammonia is used by micro algae efficiently as the source of nitrogen; phosphorus and sulphur is also provided. Carbon is provided to the algal growth medium in the form of CO_2 which inturn dissolves in water to form carbonic acid. Elements such as Mg, Ca, Mn, Zn, Cu and Mb and vitamins, are added for the effective growth (56, 63, 64 and 59).

Mixing acts as the most essential and inevitable process in maintaining micro algal system as it ensures uniform mixing of essential nutrients and gases. This mixing is established by using certain mechanisms such as stirring, pumping and injection of gases into the medium. But, this system also exhibits inefficiency and suffers lacunae with respect to damage caused to the membrane integrity of delicate algal cells, damage to the cell wall and other cellular components (65).

4. Harvesting of the micro algal cells

Micro algal cells can be harvested by means of sedimentation, centrifugation, flocculation, membrane filtration, ultrasonic separation *etc*., (59 and 66). Harvesting of the micro algae generally involves two steps viz., bulk harvest and thickening. In case of bulk harvest micro algal cells are separated from the medium where it was suspended and thickening of the collected slurry was enhanced by means of density gradient centrifugation or filtration (21).

5. Significance of micro algae and its byproducts

Microalgae contain up to 50-70% protein, 30% lipids, over 40% glycerol, up to 8 - 14% carotene and high concentration of vitamins B1, B2, B3, B6, B12, E, K, D, *etc*., compared to terrestrial plants and animals (67). It also contains fiber, poly unsaturated fatty acids and pigments such as canthaxanthin, chlorophyll, phycoerythrin, fucoxanthin, phycocyanin, B-carotene, astaxanthin, lutein, zeaxanthin and known to exhibit antiviral, anti microbial and fungal activity. Micro algae are the important source for the production of biodiesel. The *Chlorella vulgaris*, *Haematococcus pluvialis*, *Dunaliella salina* and the *Cyanobacteria*, *Spirulina maxima* are gaining world wide popularity as an eminent source of protein (68). Micro algal species such as *Chondrus crispus*, *Mastocarpus stellatus*, *Ascophyllum nodosum*, *Alaria esculenta*, *Spirulina platensis*, *Nannochloropsis oculata*, *Chlorella vulgaris* and *Dunaliella salina* are used by the cosmetic industry for the production of anti aging; sun rays protection creams, fairness creams, body lotions and hair color additives (69). *Dunaliella salina* is grown as a source of green photosynthetic pigment, beta-carotene. Beta-carotene is used as an orange dye and as a source of vitamin C . *Dunaliella* sp, *Chlorella* sp, and *Spirulina* sp, are three major types that have been used to produce highly valuable compounds such as lipids, protein and pigments (70, 71 and 72). Blue green algae belonging to genera *Nostoc*, *Anabaena*, *Tolypothrix* and *Aulosira* fix atmospheric nitrogen thus are used as inoculants for paddy crop grown both under upland and low land conditions. Anabaena in association with water fern Azolla fixes atmospheric nitrogen symbiotically to the tune of 60 kg/ha/season and enriches soils with organic matter (73). *Chlorella vulgaris*, *Chlamydomonas pyrenoidosa* exerts antibacterial activity against both Gram-positive and Gram-negative bacteria

under in vitro condition. It has also been reported that microalgae, such as *Ochromonas* sp., *Prymnesium parvum* and many blue green algae produce toxins that may have potential pharmaceutical applications (74 and 75). Microalgae feeds are used for the culture of larvae and juvenile shelland finfish, as well as for raising the zooplankton required for feeding of juvenile animals (76). The most frequently used species in aquaculture are *Chlorella, Tetraselmis, Isochrysis, Pavlova, Phaeodactylum, Chaetoceros, Nannochloropsis, Skeletonema* and *Thalassiosira*. Mainly, the microalgae *Spirulina* and, to some extent, *Chlorella* is used in this domain for many types of animals such as cats, dogs, pigs, goats, poultry, aquarium fish, ornamental birds, horses, cows and breeding bulls (8). C. *protothecoides* is regarded as a suitable microalga for the production of biodiesel. Biodiesel was comparable to oil-based diesel and complies with the US Standard for Biodiesel (77, 78 and 79). C. *vulgaris* is used in the waste water treatment (80, 81 and 82).

6. Advantage of micro algae cultivation over terrestrial plants

Micro algae can produce large biomass in the short period compared to terrestrial plant.

1) It can sequester CO_2 present in the atmosphere and flue gas and helps in the mitigation of global warming more efficiently than terrestrial plants (1 kg of dry algal biomass utilize about 1.83 kg of CO_2).
2) It needs less water than terrestrial plants.
3) It can be grown on fresh water, sewage water and brackish water.
4) It can be grown using sewage, waste and polluted water and thus aid in bioremediation by removing nitrate, phosphates and other harmful contaminants.
5) It doesn't need the application of fungicides, herbicides and pesticides during their cultivation.
6) It yields several byproducts of natural and industrial importance.
7) It is an eco friendly methods helps in the restoration of already deteriorated environment (21, 23 and 25).

7. Conclusion

Micro algae are the diverse group of microscopic chlorophyllous creatures with the wide range of physiological and biochemical diversity capable of growing at a wide range of aquatic environment, accumulating carbohydrates in them by fixing CO_2 present in the atmosphere, growth medium and industrial exhaust flue gas. These micro algae are capable of producing large biomass in short time and yields several economically, ecologically and industrially important byproducts compared to terrestrial vegetation. Micro algae thus act as a potential tool in combating global warming and climate change and could also alleviate economical distress of an individual, society and country in a sustainable way.

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Author Profile

Avinash D Patil (M.Sc. Agri) (Agricultural Microbiology), Kalaburgi- 585102, Karnataka (India)