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Review Article

Carbon Dioxide Capture, Tolerance and Sequestration Using Microalgae- A Review

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ABSTRACT

Global warming is main issue faced by world at present, caused due to emission of various greenhouse gases like CO_2, CH_4, N_2O and Fluorocarbons. These gases are released in the atmosphere due to various anthropogenic activities like burning of fossil fuels, flue gases from power plants, etc. Anthropogenic carbon dioxide has been identified as a major cause for global warming. There are various methods available for CO_2 sequestration, biological methods of sequestration using algae are energy proficient due to less energy requirement. Green algae can secretive CO_2into sugars and lipids in nearness of daylight by compound activity and drop CO_2 to certain level. Algae can be used to capture CO_2 from various industries like steel, cement, power plants, automobiles and many others by cultivating its near the industrial area.

Keywords: Carbon dioxide, Sequestration, Microalgae and Tolerance.

INTRODUCTION

Algae is used as a resource of food, fuel, stabilizing agent , manure, compound and in waste water treatment as well as in power plants to lessen CO_2 discharge. Algae generates a large amount of biomass and energy. Certain species of algae gather upto 60% intracellular lipid of their overall biomass, it enhance their heat of combustion and energy value. More than 70,000 algae have been identified but every single one of them are not well for human necessity. Algae can be grown under conditions which are not suitable for regular crops production like Soyabean and others. Microalgae can manage CO_2 using solar energy with efficiency ten folds better than terrestrial plants. Fifty percent of the photosynthesis process on Earth by algae[1].

Enlarged concentration of carbon dioxide in the atmosphere is getting a immense deal of consideration as it is answerable for global warming. Amount of fossil fuels being burned is positively related to atmospheric increase of carbon dioxide[2]. In order to retard this increase of carbon dioxide, most industrialized countries have joined a policy to hold carbon dioxide emissions[3]. Photoautotrophic algal cultures have the potential to diminish the release of into the CO_2 atmosphere, helping alleviate the trend towards global warming. To realize workable CO_2 biological fixations systems, selection of optimal microalgae is vital[4]. The selection of optimal microalgae depends on specific strategies required for CO_2 sequestration. Micro-algal biomass creation has huge potential to add up to world energy supplies and to control CO_2 emissions as the demand for energy increases. This technology makes creative use of arid and semi-arid lands and highly saline water, resources that are not appropriate for agriculture and other biomass technologies[5].

Greenhouse gases in the atmosphere & its contributions

The effect of greenhouse gases depends on the chemical nature of various gases and its quantity. For example, the effect of methane and CFC are extremely elevated even if they are present in lower quantities. Water vapor dominates the greenhouse effect among contributing gases, CO_2 plays major role as it

influences the increase of water vapor concentrations.
Table 1 shows the various greenhouse gases and their contributions. From above table, it is observed that, among all greenhouse gases, input of carbon dioxide to the environment is considered to be the maximum[6].

Different ways to reduce CO_2
The majority of the World's energy supply take place from fossil fuel, as a result there is increase in the atmospheric CO_2 leading to global warming. Therefore, it is extremely vital to develop new methods for CO_2 sequestration and also to develop an another clean energy sources which do not depend on fossil fuel and have a bearable environmental impact. Oceans play a vital role in absorbing atmospheric carbon dioxide but absorption of carbon dioxide by ocean is slow process and can take hundreds of years. Due to recent researches, the scientists had came across the techniques of carbon dioxide confiscation and bio-fuel creation from micro and macro algae. This method turn out to be one of the option to fight climate change as higher plants have diverse restrictions to be utilize as a ideal scheme for carbon sequestration and bio-fuel production. Abundant work have been done on carbon confiscation with bio-fuel production by algae but still it needs much research in order to meet the increasing demand for energy. In order to reduce atmospheric CO_2, to combat Global Warming the use of fossil fuels should be replaced[7]. Microalgae can be widely used to seize CO_2 from power plants, steel, cement, oil, automobiles and many other industries and successive algal biomass can't be practice for bio-fuel creation but also for various industrial products[8].

CO_2 sequestration using microalgae
Algae are recognized as one of the oldest life-forms[9]. They are photoautotrophic primitive plants which lack roots, stems and leaves, have no disinfected covering of cells around the reproductive cells[10]. Algae size can range from 1micron to a few hundred microns in size. Microalgae are one of the most important groups of organisms on the Planet, it produces approximately half of the atmospheric oxygen on the earth, while consuming vast amounts of the greenhouse gas carbon dioxide. Microalgae have a fast growth ability and lots of species have oil content in the range of 20-50% dry weight of biomass[9]. 1kg of dry algal biomass utilizes about 1.83 kg CO_2[9]. Also, algal cultivation does not require herbicides or pesticide application[13]. They can produce valuable co-products such as proteins and as well biomass remainder after oil removal which may be used as fermented to produce ethanol or methane[14].

CO_2 tolerance of microalgae
Direct utilization of strength plant flue gas has been taken into consideration for CO2 sequestration systems[15]. The advantage of utilizing flue gas is the decrease of the cost of separating CO_2 gas. Since power plant flue gas contains a higher concentrations of CO_2 make out high CO_2 tolerant species is significant. Cyanidium caldarium[16] and some other species of Cyanidium can grow in pure CO_2[17]. Other CO_2 tolerant species is Euglena gracilis. Growth of this species was enhanced under 5%-45% concentration of CO_2. The most superb increase was monitored with five% CO2 attention. However, species did not grow under greater than 45% CO_2[18]. Scenedesmus species could grow under 80% CO_2 conditions but the maximum cell mass was observed in 10%-20% CO_2 concentrations[16]. Phototrophic microalgal development needs a supply of carbon dioxide as a carbon source. CO_2 supply contributes to control the pH of the culture[19]. Chemical analysis has revealed that algal biomass consists of 40% to 50% carbon, which suggest that about 1.5 to 2.0 kg of CO_2 is required to produce 1.0 kg of biomass[20]. The principal point of all considerations relating to the CO_2 budget is that, CO_2 must not reach the upper concentration that produces inhibition and must never fall below the minimum concentration that confines intensification[21]. These highest [inhibition] and lowest [limitation] concentrations vary from one species to an additional and are not yet sufficiently identified, vary from 2.3×10^{-2} M to 2.3×10^{-4} M[21,22].
Above table 2. Summarizes the CO_2 tolerance of various species. Note that some species may tolerate even higher carbon dioxide concentrations than listed in the table.

Factors influencing CO_2 tolerance
The presence of oxygen plays a vital role in controlling the efficiency of CO_2 uptake. Becker calculated that a concentration of CO_2, as small as 30ppm is adequate to carry on unlimited photosynthesis of the algae[32]. Experiments with distinctive O_2 absorption in the medium have revealed the photosynthesis efficiency is increased by 14% if almost no O_2 is present in the medium but it is reduced to 35% when the medium is saturated with 100% O_2. Other study showed that oxygen concentrations ranging from 10-200% of ambient had no significant

effects on daily carbon gain or total damp biomass creation pace in this certain seaweed[33]. The effects of various combinations of CO_2 concentration, light intensity and oxygen concentration on photosynthesis and growth in numerous algal category propose the subsequent

- Temperature can be a determining factor in the selection of the algal species[34,35].
- The environmental condition plays an important role in promoting CO2 fixation and cellular propagation. Controlled pH from 7 to 11 required for higher growth rate[36].
- Different algae show different responses to high concentrations and high light intensities. Inhibition of photosynthesis [CO2 fixation and growth], increase with escalating oxygen concentration and with growing light intensity[32-37].
- Basic growth nutrients must be available in order to keep appropriate physiological combination of the culture[38-40].

CONCLUSIONS

Use of microalgae for CO_2 sequestration is unique technology. Microalgae shows reasonable tolerance to the temperature and CO_2, hence, sequestration is done with maximum efficiency. By selecting adequate species, microalgae can assimilate CO_2 within various ranges of concentration. Adapting microalgae for the use of CO_2 sequestration also has the potential to make helpful byproducts and may possibly perform versatile. In addition, it is an environmentally friendly technology. Here is a range of industrial answer feasible microalgae based CO_2 sequestration systems and thus, optimal microalgae in work would vary from scheme to scheme. Efforts to find the "ideal" microalgae species will continue, planned engineering evaluation and engineering alteration will be taken into great consideration to realize effective micro-algal CO_2 sequestration systems.

Table 1: Greenhouse gases and their contributions

Greenhouse gases	Greenhouse Effect%	Natural %	Man-Made %
Water vapor	95.000	94.999	0.001
Carbon dioxide	3.618	3.502	0.117
Methane	0.360	0.294	0.066
Nitrous Oxide	0.950	0.903	0.047
Misc. gases	0.072	0.025	0.047
Total	100	99.72	0.28

Table 2: CO_2 Tolerance of various species.

Species	Known Maximum CO_2	Concentration References
Cyanidium caldarium	100%	23
Scenedesmus sp.	80%	16
Chlorococcum littorale	60%	24
Synechococcus elongates	60%	25
Euglena gracilis	45%	18
Chlorella sp.	40%	26
Eudorina sp.	20%	27
Dunaliella tertiolecta	15%	28
Nannochloris sp.	15%	29
Chlamydomonas sp.	15%	30
Tetraselmis sp.	14%	31

Table 3: Parameters required for algal growth

Parameters	Range	Optima
Temperature [^{0}C]	16-27	18-24
Salinity [gl^{-1}]	12-40	20-24
Light intensity [Lux]	1000-10000 [depends on volume & density]	2500-5000
Photoperiod [light dark hrs]	--	16:8 min; 24:0 max
pH	7-9	8.2-8.7

REFERENCES

1. Goldman Joel C, Porcella Donald B, Middlebrooks Joe E, Daniel F and Toerien. The effect of carbon on algal growth- its relationship to eutrophication. Utah Water Res Lab. 1971.
2. Stepan DJ, Shockey RE, Moe TA and Dorn R. SUBTASK, 2.3- Carbon Dioxide Sequestering Using Microalgal Systems. U.S. Department of Energy, National Energy Technology Laboratory. 2001.
3. Hileman B. U.S. Urged to Change CO_2 Emissions Policy," Chemical Engineering News. 1992;70(1):16-22,doi:10.1021/cen-v070n008.p016
4. Arizona Department of Environmental Quality. Arizona guidance manual for constructed wetlands for water quality improvements. Arizona Department of Environmental Quality, Arizona. 1995.
5. Fike JH, Parrish DJ, Alwang J and Cundiff JS. Challenges for Deploying Dedicated, large-scale, Bio-energy Systemsin the USA. Perspectives in Agriculture, Veterinary Science, Nutrition and Natural resources. 2007;2(64):1-28.
6. Balakumar K, Sharpudin J, Mubarak Basha H and Mohmmed Fareed H. Comparative Study of Carbon Sequestration by Algae in Domestic Sewage and /industrial Effluent. International Journal of Emerging Technology and Advanced Engineering. 2014;4(3).
7. Dinabandhu Sahoo, Geetanjali Elangbam and Salam Sonia Devi. Using algae for carbon dioxide capture and bio-fuel production to combat climate change. Phykos. 2012;42(1):32-38.
8. Ritschard RL. Marine algae as a CO_2 Sink. Water, Air and Soil pollution. 1992;64:289-303.
9. Falkowski PG and Raven JA. Aquatic photosynthesis. London: Blackwater Science. 1997;375.
10. Lee RE. Phycology. New York: Cambridge University Press. 1980.
11. Chisti Y. Biodiesel from microalgae. Biotechnology Advances. 2007;25(3):294-306.
12. Metting FB. Biodiversity and application of microalgae. Journal of Industrial Microbiology 1996; 17(5-6):477-89.
13. Rodolfi L, Zittelli GC, Bassi N, Padovani G, Biondi N and Bonini G. Microalgae for oil: strain selection, induction of lipids synthesis and outdoor mass cultivation in a low-cost photobioreactor. Biotechnology and Bioengineering. 2008;102(1):100-12.
14. Hirano A, Ueda R, Hirayama S and Ogushi Y. CO_2 fixation and ethanol production with microalgal photosynthesis and intracellular anaerobic fermentation Energy. 1997;22(2-3):137-42.
15. Benemann JR. Utilization of carbon dioxide from fossil fuel- burning power plants with biological system. Energy conversation and management. 1993;34(9/11):999-1004.
16. Hanagata N, Takeuchi T and Fukuja Y. Tolerance of Microalgae to High CO_2 and High Temperature," Phyto-chemistry. 31(10):3345-3348.
17. Graham LE and Wilcox LW. Algae. Prentice-Hall, Inc., Upper Saddle River. 2000.
18. Nakano Y, Miyatake K, Okuno H, Hamazaki K, Takenaka S, Honami N, Kiyota M, Aiga I and Kondo J. Growth of Photosynthetic Algae Euglena in High CO_2 Conditions and its Photosynthetic Characteristics. Acta Horticulture. 1996;440(9):49-54.
19. Brown LM. Uptake of Carbon Dioxide from Flue Gas by Microalgae," Energy Conversion and Management. 1996;37(6-8):1363-1367.
20. Sobczuk TM, Camacho FG, Rubio FC, Fernandez FGA and Grima EM. Carbon Dioxide Uptake Efficiency by Outdoor Microalgal Cultures in Tubular Airlift Photobioreactors," Biotechnology and Bioengineering. 2000;67(4):465-475.
21. Rados S, Vaclav B and Frantisek DD. CO_2 Balance in Industrial Cultivation of Algae," Archives of Hydrobiology. 1975;46(12):297-310.
22. Lee YK and Hing HK. Supplying CO_2 to photosynthetic Algal Culture by Diffusion through Gas-Permeable Membranes. Applied Microbiology and Biotechnology. 1989;31(3):298-301.
23. Seckbach J, Grossand H and Nathan MB. Growth and Photosynthesis of Cyanidium Caldarium Cultured under Pure CO_2. Isarel Journal of Botany. 1971;20:84-90.
24. Kodama M, Ikemoto H and Miyachi S. A Ne species of Highly Suitable CO_2-tolerant Fast-Growing Marine Microalga Suitable for High-Density Culture," Journal of Marine Biotechnology. 1995;36(6-9):763-766.
25. Miyairi S. CO_2 Assimilation in a Thermophilic Cyanobacterium," Energy

Conversion and Management. 1995;36(6-9):763-766.
26. Nagase H, Eguchi K, Yoshihara K, Hirata K and Miyamoto K. Improvement of Microalgal NOx Removal in Bubble Column and Airlift Reactors. Journal of fermentation and Bioengineering. 1998;86(4):421-423.
27. Yoshihara K, Nagase H, Eguchi K, Hirata K and Miyamoto K. Biological N OF Nitric Oxide and Carbon Dioxide from Flue Gas by Marine Microalga NOA-113. Cultivation in a Long Tubular Photobioreactor. Journal of Fermentation and Bioengineering. 1996;82(4):351-354.
28. Miura Y, Yamada W, Hirata K, Miyamoto K and Kiyohara M. stimulation of Hydrogen Production in Algal Cells Grown under High CO_2 Concentration and Low Temperature," Applied Biochemistry and Biotechnology. 1993;39-40(1):753-761.
29. Matsumoto H, Shioji N, Hamasaki A, Ikuta Y, Fukuda Y, Sato M, Endo N and Tsukamoto T. Carbon Dioxide Fixation by /microalgae Photosynthesis Using Actual Flue Gas Discharged from a Bioler. Applied Bio-chemistry and Biotechnolgy. 1995;51-52(1):681-692.
30. Hirata S, Hayashitani M, Taya M and Tone S. Carbon Dioxide Fixation in Batch Culture of Chlorella sp. Using a Photobioreactor with a Sunlight-Collection Device. Journal of fermentation INEERING. 1996;81(5):470-472.
31. Hirata S, Taya M and Tone S. Characterization of Chlorella Cell Cultures in Batch and Continous Operation under a Photoautotrophic Condition. Journal of Chemical Engineering of Japan. 1995;36(6-9):1363-1367.
32. Becker EW. Microalgae: Biotechnology and Microbiology," Cambridge University Press, Cambridge. 1995.
33. Kubler JE, Johnston AM and Raven JA. The effects of Reduced and Elevated CO_2 and O_2 on the Seaweed Lomentaria Articulate. Plant, Cell and Environment. 1999;22(10):1303-1310.
34. Caron DA, Goldman JC and Dennet MR. Effect of Temperature on Growth, Respiration and Nutrients Re-generation by an Omnivorous Microflagellate. Applied and Environmental Microbiology. 1986;53(6):1340-1347.
35. Brennan L and Owend P. Biofuels from Microalgae- A Review of Technologies for Production, Processing and Extractions of Biofuels and Co-Products. Renewable and Sustainable Energy Reviews. 2010;14(2):557-577.
36. Hsueh HT, Chu H and Yu ST. A batch study on the Bio-fixation of Carbon Dioxide in the Absorbed Solution from a Chemical Wet Scrubber by Hot Spring and Marine Algae. Chemosphere. 2007;66(5):878-886.
37. Kondo J. Growth of Photosynthetic Algae Eulgena in High CO_2 Conditions and Its Photosynthetic Characteristics. Acta Horticulture. 1996;440(9):49-54.
38. Mcginn PJ, Dickinson KE, Bhatti S, Frigon J, Guiot SR and O'Leary SJB. Integration of Microalgae Cultivation with Industrial Waste Remediation for Bio-fuel and Bio-energy Production: Opportunities and Limitations. Photosynthesis Research. 200.
39. Andersen RA. Algal Culturing Techniques. Elsevier Academic Press, Burlington. 2005.
40. Carvalho AP, Meireles LA and Xavier F. Microalgal Reactors: A Review of Enclosed Systems Designs and Performances. Biotechnology Progress. 2006;22(6):1490-1506.