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A Recent Approach in Algal Method of CO_2Fixation and the Need for the Execution of Research into Reality

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Abstract

Indian medical association had announced health emergency in national capital New Delhi, as it has recorded severe air quality asthe intensity of pollution crossed it's limit. The concentration of atmospheric pollutants like CO_x,NO_x,SO_x, CFC'sare steadily rising due to the anthropogenic activities especially because of clearing of forests and an increased demand for energy(Sudhakar*et al.,* 2011)which has increased atmospheric Carbon dioxide (CO_2) concentration on earth that influencesthe climatic changes around theworld. Climate change is a threat to the sustainable development (IPCC 2014), among these pollutants, legitimate administration of carbon elimination is necessary from a worldwide point of view. According to the NASA, the planet's overall average surface temperature has been raised about 1.1^{0}C since the late 9th century. Before the industrial revolution, CO_2 level was about 280ppm and current level is greater than 380ppm. Hence, the immediate need for mitigation of $CO_2$is gaining importance.Even though Chinesestarted using algae since 2000 years ago (Spolaore*et al.,* 2006), humans are unaware of algal photosynthetic capabilities. Since last century, the importance of algae becomes familiar to the scientific communities. Comparing to the plants, microalgae found most effective in mitigating CO_2, 50% of overall biomass of microalgae is obtained from carbon dioxide (Mirón*et al.,* 2003). About, 100 tons of microalgae biomass fixes 183 tons of CO_2(Huang and Zhang, 2014). This paper gives insights on the recent approaches and developments in the field of algal technology in CO_2mitigation with reference to the comparative studies on biomass production, at different level of CO_2concentration.

Keywords: Carbon dioxide, CO_2 mitigation, microalgae, Biomass.

Introduction

The concentration of CO_2in the atmosphere has already reached 380 parts per million,up 100 ppm from its pre-industrial value(Rahaman*et al.,* 2011; Singh and Ahluwalia, 2013). According to the NASA, over the past 50 years, near-surface air temperatures across Alaska and the Arctic have increased at a rate more than twice as fast as the global average.NASA's earth observatory informed that polar region drastically decreasing in overall ice mass at the region ofAlaska due to the rise in average temperature of earth.Recently, India also faced such climatic variations where in, Indian medical association had announced health emergency in national capital, as New Delhi recorded severe air quality. Emissions from domestic fires and motor vehicles have similarities in composition, toxicity, and exposure characteristics are the major contributor to the CO_2concentration to the atmosphere (McCreanor*et. al.,*2007).
India is a developing country it is going to depended on coal reserve for its future economic growth. This is a matter of concern(DOE, 2006).Hence, we arelooking forward for the carbon neutrality and such technologies.Many researches showed that the major causes behind the global warming areheat trapping gases likeCO_X, N0x,SO_x and CFC's (Wuebbles*et.al.,* 1989). Evidences showed that the concentration of atmospheric pollutants steadily rising which can influence the world climate change directly.The planets overallaverage surface temperature has been raised about 1.1^{0}Csince thelate 9thcentury and global sea level rose about 3mm/year (Fletcher, 2009) since last century the rate has been rapidly doubled.

Changedriven largely by increased $CO_2$and other human made and industrial activities emissions into atmosphere (Solomon*et al.* 2009*)*. The global concentration of CO_2in our atmosphere today far exceeds the natural range.Due to which the global temperature raised 0.8^{0}C during the last 100 years (NCDC, 2007). According to the IPCC – 2014, special reports on emission scenario by current atmospheric concentration of $CO_2$is about 30% higher than they were about 150 years ago at the dawn of the industrial revolution (Nakicenovic *et al.,* 2000). To combat the global warming and pollution problems thus actions are being taken to mitigate the greenhouse gas emissions especially CO_2. As the amount of CO_2 increased since past century (Canadell*et al.,* 2007) humans need sustainable approaches which could be eco-friendly in nature.

This literature review deals in detail about the trends in biological methods of CO_2 sequestration and also trying to appreciate the fighting spirit of the global scientist in combating the rising pollution and global warming crisis, and mainly focuses on the importance of algae in CO_2sequestration. Presently biological method has been considered as most promising option for CO_2mitigation (Singh*et al.,* 2018). The mechanism behind this mitigation was understood on exploring photosynthetic activity of plants which play a major role in recycling atmospheric CO_2.Terrestrial plants fix about 500 billion tons of CO_2per annum (Xie *et al.,* 2014). Due to the globalisation effects clearance of forests and increasing pollution sources humans need to search for the alternative sources. According to the Sudhakar*et al.,* (2011), only a km^2 ofbiological carbon sequestration algal technology itself is enough to completely recover 1500 million tons of CO_2 produced by India.

Micro algae, Macro algae, and Cyanobacteria became alternative for the terrestrial plants for CO_2 mitigation(Patil*et. al.,* 2008; Brown and Zieler,1993) as microalgae proved to be the most efficient fixing agent of CO_2 (Pokoo-Aikins*et al.,* 2010).In addition to this, microalgae are potential producer ofmany other metabolites and bio-fuel. Interestingly, it is reported that the CO_2 fixing ability of plants is approximately 2 times less than that of micro algae.(Mishra*et al.,* 2013). Both plants and micro algae are photosynthetic and autotrophs. However the growth time for algae is less (Lee *et al.,* 2003), unlike higher plants, microalgae don't require a vascular framework for supplement transport, as each cell is photoautotrophic with specifically engrossing supplements. Microalgae cells are daylight driven cell manufacturing plants that can change over CO_2into use full high value bio-active materials. (Spolaore*et al.,* 2006;Milledge, 2013;Razzak*et al.,* 2013).These properties of micro algae gain the advantage over the plants and algae can be grown quickly compared to the terrestrial plants and within a few hours, cell concentrations of some species havebeen doubled (Moreira and Pires, 2016). Microalgae have as of late increased tremendous consideration around the world, to be the important feedstock for sustainable power source creation, because of their high development rates, high lipid productivities and the capacity to sequester carbon(Chisti,2007).

Therefore, microalgae are considered as promising organism.The photosynthetic procedure of algae utilizes atmospheric CO_2 and from pipe gases to blend supplements for their development. (Cheah*etal.,* 2015). Early experiments were focused much on single algal culture (pure culture of algae) maintenance forCO_2 mitigation. But pure culture requires specified conditions, to be grown in Laboratories and the maintenance of specified required conditions for longer duration was a tedious process.

Monoculture Algae in Co_2 Mitigation:

Various researchers worldwide extensively worked on the algae, earlier focused on monoculture(pure culture) algal technology andexposed the various aspects of algal behaviours.Negoro*et al.,* 1991, reported with the input of CO_2 of about 15%, along with the various other components, and *Nannochloropsissp*. Fixed 564 Mg $L^{-1}D^{-1}$ of $CO_2$and in the same conditions the*Nannochloris* fixed 658Mg L^{-1} $D^{-1}$of CO_2. With the supplementation of 20% of CO_2*Chlorella sp*. fixed about 1316 mg L^{-1} d^{-1}along with the presence of other factors (Sakai *et al.,* 1995).While with increase of $CO_2$of about 2.5 fold(50%), the*chlorella* sp. Only fixed 1790Mg L^{-1} D^{-1}. That accounts about 1.4 fold fixations.(Maeda *et al.,* 1996). *Chlorogliopsis sp.* at the input of 15% of CO_2 only fixed about 20.45 mg L^{-1} d^{-1}(Ono and Cuello 2007)**(Table 1.)**.

Table 1. Monoculture algae in CO_2mitigation and their efficiencies:

Sl. No.	Microalgae	CO_2 input (%)	Rate of Fixation (%)	Reference
1.	*Chlorella vulgaris*	0.15%	55.3%	(Cheng *et al.,* 2006)
2.	*Spirulina sp.*	7%	27%	(Cheng *et al.,* 2006)
3.	*Scenedesmus obliquus*	13%	38%	(Cheng *et al.,* 2006)

CO_2 Tolerance in microalgae:

The previous studies showed that CO_2 tolerance level varies from one species to other (OnoE and Cuello 2003).Chlorella sp. just develop under 2% (v/v) of CO_2; additional increment of CO_2 will suppress their development(Lam *et al.,* 2012). Above 5% input of CO_2 to the microalgae culture will inhibit the growth of microalgae**a**nd continuouslyexposing the micro algae to the flue gases will also resist the growth of microalgae due to the presence of nitrogen oxides and sulphur oxides, which are source of toxic to the microalgae (Ramanan *et al.,* 2010; Zhao and Su, 2014).AlgalCO_2 fixation efficiency were reduced from 7-17% to 4-9% under 12%CO_2input.(De Morais and Costa 2007) and CO_2 concentration above 15% -20% is also inhibiting the growth of the *chlamydomanas* (Spalding2007).

However most of the experiments were carried in an open pond systems. Continuously supplying the CO_2, and exposing the same light conditionfor longer duration had shown reduced fixing rates. Pulz **(**2001) reported, decline in the photosynthetic ability because of the continuous exposure to the high temperature the solubility of CO_2 get reduced. In an experiment conducted by the Phatarpekar***et al., (*2000),** the concentration of chlorophyll-a, lipid and particulate natural carbon in monocultures is less compared to the blended culture. The figured dietary energy content was essentially higher (P<0.05) in the blended culture contrasted with the monocultures amid all the development stages.

Blended Culture Algae in CO_2Mitigation:

Later, researches considered the blended culture of microalgae for better mitigation of $CO_2$and have a greater potential at commercial scale(Dalrymple*et al*. 2013) Thus, the monoculture of algae found least important over blended culture.According to the study conducted by the Mishra*et.al.(*2013)within a single day 50% of the CO_2 feed was successfully degraded by the blended culture of the microalgae. However, monoculture of *chlorella sp*. cleared CO_2 gas only up to the concentration of 15% in an experiment carried in photo bioreactor using *chlorella spp*. by the Fulke*et al.,* (2010)**(Figure 1.)**.

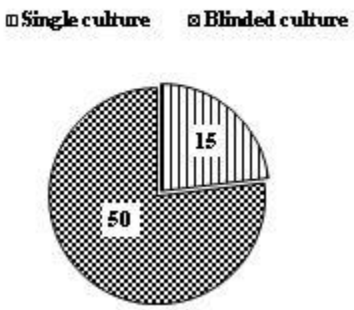

Fig 1. Comparison of CO_2sequestration between monoculture algae and blended culture algae.

Along with the *chlorella sp*., Scenedesmus *sp.* is also a better option for CO_2 mitigation. *Scenedesmusdimorphus* can fix 1.27g/l/d of CO_2, *Scenedesmusincrassatulus* can fix 1.50g/l/d of CO_2, *Scenedesmusobliquus* can fix up to 0.55g/l/d of CO_2 and can tolerate 10% CO_2, and it can fix 1.19g/l/d of CO_2 at 2.5% of CO_2 concentration. (Fulke *et al.,* 2010). In one study shu*et.al.,(*2013)reported that the blended culture of *chlorella* and *S.cerevisiae* performed appreciable symbiotic relationship and rate of CO_2 mitigation 64.76 mg^{-1} $L^{-1}h^{-1}$ which is equal to 195% higher than that of the *chlorella sp*. alone can fix.According to the Bose*et.al,*(2011) the combination of algae and bacteria along with cyanobacteria serve for multipurpose applications. In certain stressed conditions these combined species may play an effective role in combating the challenging conditions, in which single species alone can't survive.
In an experiment conducted by Rinanti*et.al.,*(2014)proved that the blended culture algae can tolerate high level of CO_2 input however study suggested that aeration should be maintained between 2-5$Lmin^{-1}$. Mixed culture of Chlorella *sp., Scenedesmus sp. A*nd *Ankistrodesmus sp.* Can fix about 0.98 and 0.85 $g^{-1}L^{-1}d^{-1}$ of CO_2 at 5-10% input of CO_2 respectively. And removal percentage is 59.80 and 63.10.

Thus assimilated blended culture found best in CO_2 degradation as compared to the monoculture algae as reported in previous studies (Skjånes*et al.,* 2007). Advances in the field of CO_2 sequestration from algae found many better approaches, in one study conducted by the Ramramanan *et al., (*2010) interestingly it was found that calcite formation is associated with better sequestration of CO_2 this may serve as another route to sequester carbon. As most of the cyanobacteria and microalgae are actively involved in the precipitation of calcite, consequently this approach was started with an idea of accomplishing higher CO_2 obsession rates in industrial applications and achieved satisfactory results. The graphical representation of CO_2 sequestering ability of two species studied in this experiments is shown below.

Fig 2. and Fig 3. Indicate that, in this experiment *Chlorella sp*. indicated amazing sequestration productivity. This strain showed higher development and along these lines higher sequestration proficiency in 10 days of experimental run. Comparatively *platensis* showed slower development with lesser sequestration effectiveness. However in presence of calcite depositions these two species mean CO_2 fixation efficiency increases to 1.5–2.5 folds.

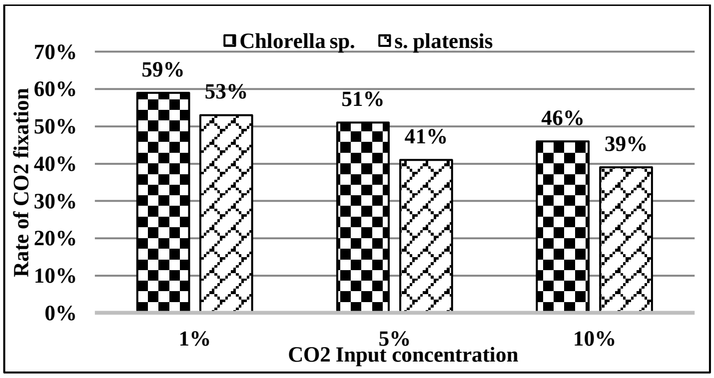

Fig 2. Comparative Studies of CO_2Fixing Ability of Chlorella and Platensis Sp. In Absence of Calcite Deposits

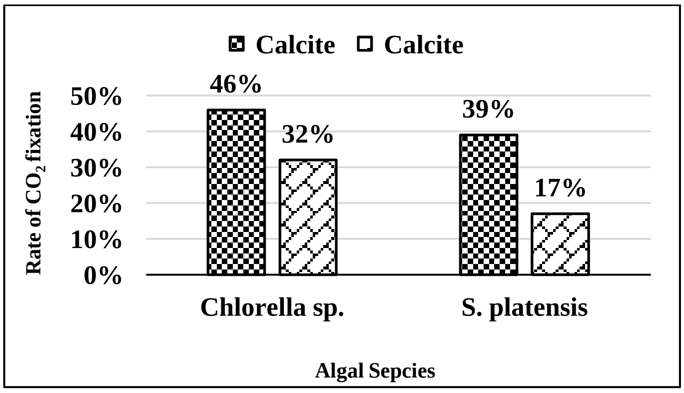

Fig 3. Comparative Studies of CO_2Fixing Ability of Chlorella and Platensis Sp. In Presence of Calcite Deposits.

Ramanan *et al.,* (2010) reported that, the same species achieved greater level of CO_2in presence of calcite deposition with the input of 10% CO_2chlorella achieved mean CO_2sequestration level of 46% however in absence of calcite it only sequestered 32%. In case of *S.platensis* with the input of 10% CO_2 in presence of calcite deposition its sequestration ability is 39% and in absence only 17% (Fig). From these results one can conclude that, chlorella species supplemented with the calcite will effectively sequester the CO_2. Compared to the monoculture and blend culture. Researchers observed a peculiar thing that, up to certain level of CO_2 concentration these two species produced considerable algal biomass as well as better phenomenon of photosynthesis. However above certain limit, biomass as well as CO_2sequestering ability of these organisms was reduced drastically. Which is proved by another group of researchers, (Morais and Costa, 2007). The algae did not have a Lag phase at fixation higher than the atmospheric concentration which suggests photosynthetic ability of these living beings is restricted by atmospheric CO_2 concentration.

From this we can conclude that the algal species have their own photosynthetic activity limit above which they cannot absorb CO_2 and their bio mass production also drastically stopped. The low atmospheric

CO_2concentration is a limitation. Integrated approaches like physiochemical and CO_2feeding to the culture may enhance capturable efficiency (Moreira and Pires 2016). *Chlorella* sp. is known to be a high CO_2 fixing organism (Miyachi *et al.,* 2003). Which has been validated once again in the study conducted by the Ramanan *et al.,* (2010)Calcite production coupled with CO_2 sequestration happens naturally in both fresh and marine water bodies. (Shiraiwa, 2003).Which serves as an added advantage for certain microalgae for better mitigation of CO_2.

Conclusion

In conclusion, channelizing the micro algae to precipitate the calcite in calcium carbonate containing conditions more efficiently,so that we can achieve better CO_2 sequestration which is the most challenging aspect before researchers. Some researchers worked on enhancing the precipitation capabilities of certain bacteria, where for enhancing the precipitation of calcite by using the cynechococcus and recorded the algae grown in calcium ion rich culture media shown a deposition of ca+ in their cell wall however blanks without calcium ion in their culture did not shown any deposition of ca+ their cell wall (Dittrich *et al.,* 2003). Most importantly research should focus on understanding the photosynthetic phenomenon in algae where understanding the molecular aspect of photosynthetic activity one can regulate process using the advanced biotechnological and genetic engineering tools. So that, the CO_2 utilisation efficiency can be enhanced by which one can achieve a better CO_2fixation. Along with these approaches the integrated approaches should be carried, because no single technology can completely help in combating the reduction of pollution (Fulke *et al.,* 2014). Hence, the future approaches like mentioned in this review may assist in reducing the concentration of CO_2in atmosphere and these efforts are going to be one of the milestone of scientific societies in reducing the ever rising global warming and pollution problems in future.

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