Capture of Industrial CO_2 by Algae

Subjects: Energy & Fuels

Contributor: Dmitry Pashchenko, Pavel Iglin

The importance of the cultivation of algae in various fields, including in the field of energy, is very high. Algae as a reserve type of renewable fuel are considered thanks to the rapid growth of algae and the ability of algae to store lipids.

Keywords: algae ; CO2 capture ; thermochemical regeneration ; algae cultivation

1. Introduction

The development of civilization is directly related to the increase in energy consumption. Since the beginning of the industrial revolution, more and more energy has been consumed by humanity. And as energy consumption grows, so does the output of greenhouse gases. From the mid-18th century to the early 21st century, carbon dioxide emissions increased from 3 metric tons to 8230 tons, respectively, according to the Carbon Dioxide Information Analysis Center.

One of the first important attempts to limit CO_2 emissions was the Kyoto Protocol of ’97. Its essence was that all its participants should reduce the level of greenhouse gas emissions to below 5% of the 1990 level [1]. The effect of the Kyoto Protocol has been known [2][3][4]. When the Kyoto Protocol ended, it was replaced by the Paris Agreement.

The Paris Agreement was formally implemented on 4 November 2016. Its main goal is the same as that of the aforementioned Kyoto agreement—to maintain the average global temperature. In the long term, the outcome of the Paris Agreement will be climate change mitigation [5].

In a decade, the topic of decarbonizing the energy sector has come to the fore. For example, EU countries want to abandon hydrocarbon fuels by 2030. Furthermore, many large oil and gas companies have stopped investing in the exploration of new oil and gas fields and switched to the development of alternative energy sources. Therefore, there is a request for another type of fuel—biofuel. Previously, biofuels first and second were well known. Generation first biofuels are waste of sugar, starch, vegetable oil, animal fat [6]. Biofuel of the second generation differs from the first generation in the use of non-food parts of plants—stems and husks [7]. However, there is also a relatively new, much less known biofuel of the third generation—biomass of micro and macroalgae, since algae can accumulate lipids, capture CO_2 [8], thereby utilizing greenhouse gases.

2. Capture and Sequestration of Carbon Dioxide by Microalgae

It was much devoted to the capture of carbon dioxide. Now, scientists from all over the world are actively offering a completely different approach—not only to capture CO_2 but also to immediately use it for energy reproduction. This approach to solving the greenhouse problem is very relevant because of the high cost and complexity of technologies for capturing CO_2 emissions, the same CO_2 storage facilities also need to be maintained, and they uselessly occupy a considerable area. Thus, the reproduction of biofuels together with the capture of carbon dioxide is an elegant and high-potential solution to the problem of global warming. CO2 accounts for 77% of all greenhouse gases. Thus, despite the content of nitrogen oxides, hydrocarbons, and sulfur dioxide in greenhouse gases, it is necessary to capture CO2. Therefore, if you defeat uncontrolled mass emissions of CO_2, you can also defeat a whole host of environmental problems, such as the drying up of natural freshwater, disruption of food chains, and the extinction of entire animal species, and so on.

Carbon dioxide is a stable and inert compound, so increasing the value of biofixed carbon dioxide is a major challenge. It is a detailed and in-depth one about this topic [9]. It was considered a range of technologies to increase the value of carbon dioxide, such as mineralization of carbon dioxide as an inorganic carbonate or supercritical carbon dioxide as a solvent.

It was [10] is to analyze the impact of carbon dioxide on the environment and to justify the use of CO_2 the reproduction of biofuels. By their nature, greenhouse gases in some quantities are vital for organic existence on Earth, as they absorb the thermal radiation of the Earth and reflect it. That is, greenhouse gases help to maintain a normal temperature for all living things on the planet. However, excessive amounts of greenhouse gases are already having a disastrous effect on the organic world, and their resulting amount must be reduced and constantly monitored. In addition to maintaining the number of greenhouse gases at an acceptable level, it is necessary to reduce the consumption of fossil irreplaceable natural resources, as this is also an urgent need for the survival of future generations of the planet.

For some researchers [10][11][12], it was noted that the combustion of traditional fuel brings 56% of all CO_2 emissions in the world. Carbon dioxide is captured directly from the carbon source and transported to storage.

Storage facilities must ensure safe storage of CO_2 for hundreds of thousands of years, without dumping it into the atmosphere. Speaking about this method in more detail, the stages of CO_2 capture should be distinguished: separation of the gas phase, dissolution into liquid, absorption into a solid. When dissolved in a liquid, carbon dioxide is absorbed by a special liquid solvent, then this medium is heated until CO_2 is released and the cycle is repeated. Absorption into a solid is an adsorption process performed by decreasing pressure and increasing temperature. Capturing CO_2 before direct fuel combustion is possible only when using a thermochemical gasification process.

According to Rahman, Farahiyah Abdul, et al. [10], CO_2 capture before combustion is more economical than after combustion. One of the problems of CO_2 biofixation and safekeeping technology is also an insufficiently known base from the political side. It is not enough on the exact costs of capturing and general rules for storing CO_2 . Countries need to cooperate on these issues, and this is not happening properly at the moment. Therefore, the method of long-term storage of CO_2 cannot be preferable and it must be useful to utilize it in biofuels. It was less known on the simultaneous capture of CO_2 and the production of microalgae at present, although according to the authors, this is a promising area of modern science. Microalgae can actively absorb CO_2 from the exhaust gases for photosynthesis and self-reproduction.

In Alami, Abdul Hai, et al. [13] presented a deep understanding on the use of algae as traps for CO_2 from flue gases. The quality of such syster

Bhola, V., et al. [14] claim that microalgae can biofix carbon dioxide 50 times more than plants. Algae can generate an average of about 280 tons of already dry biomass per 1 ha per year, provided that solar energy is available 9% of the time. These microalgae can absorb about 513 tons of carbon dioxide during their growth. Given the composition of the flue gases, namely the carbon dioxide content of 3–30%, the most important task is the correct selection of algae that can withstand and absorb such high concentrations of CO_2. resistant algae, then it is necessary to constantly maintain the optimal pH level. Under these conditions, the crop will be able to multiply and effectively deal with CO_2 emissions by absorbing them. Moreover, when choosing algae, you should give preference to species that are resistant to NOx and SOx, because they form acids when interacting with water, which is destructive to most crops. It is worth noting that, when cultivating algae in natural conditions (pond and sunlight), a pond with a volume of 4000m can absorb about 2200 tons of CO_2 /year.

3. Micro and Macro Algae—Rationale for the Use of Algae to Capture Carbon Dioxide

The importance of the cultivation of algae in various fields, including in the field of energy, is very high [15][16][17][18][19][20]. Algae as a reserve type of renewable fuel are considered thanks to the rapid growth of algae and the ability of algae to store lipids [21]. Kumar, B. Ramesh, et al. [22] shows not only the potential of this type of energy but also the natural insurmountable limitations of such a type of fuel as organic algae.

The energy potential of algae microalgae is very high, since it does not require complex expensive conditions for keeping and growing algae, and the compensation of non-renewable fuel is effective. If it was talked about macroalgae, then the cultivation of such crops, on the one hand, is not too difficult a task. Their cultivation can take place in their natural environment—on the seashore, where there is a lot of sun. However, here you can face the problem of seasonality. Cultivation of macroalgae in the cold, low-sun period is a technical problem. In addition, for the introduction of this type of energy as a commercial project, it is necessary to increase the discounted profitability of the project and reduce the cost of yeast and strains of viable bacteria.

There are various ways to grow algae; two common options are bioreactors and open water. The selected algae need to create conditions close to ideal for their cultivation. Each type of microalgae has its conditions. According to [23][24][25], such algae as *Spirulina* and *Dunaliella* grow best in open water bodies. *Prokaryotic* and *eukaryotic algae*, which are most often grown in a reservoir, include *Nannochloropsis* sp., *Chlorella* sp., *Tetraselmis* sp., *Arthrospira platensis*, *Dunaliella salina*, *Scenedesmus* sp., *Haematococcus pluvialis*., *Anractenaba* sp.

4. Using Micro and Macroalgae as an Energy Resource

Algae are the fastest-growing plants on the planet. Algae's ability to capture carbon makes them a promising biofuel. By maintaining precise growing conditions, which will be mentioned below, biofuels can be obtained from algae. The use of algae as a biofuel product has been focused many times [26][27][28][29][30][31][32]. For example, Mathimani, Thangavel et al. [33] investigated various types of thermochemical treatment of algae for energy and industrial purposes. Plouviez, Maxence et al. [30] point out some advantages of using microalgae, macroalgae, and cyanobacteria as energy fuel. The (**Figure 1**) demonstrate the main advantages of using algae as bio-oil. Equally of particular importance are experiments conducted with different types of algae about their lipid profile. It was found that, among the algae from the coast of Kuantan, *Nannochloropsis* sp. are the most suitable for biodiesel production. In addition, freshwater macroalgae *Rhizoclonium* sp. [34] were known as an energy source in the form of biodiesel. It were able to optimize the biodiesel production process and obtain 6.044 g of macroalgae oil with ultrasonic treatment. In addition, there is the production of bioethanol from the mass of macroalgae [35]. Fermentation was applied by the method of two-way separate hydrolysis and fermentation. As a result, it was able to confirm that macroalgae are excellent for bioethanol production.

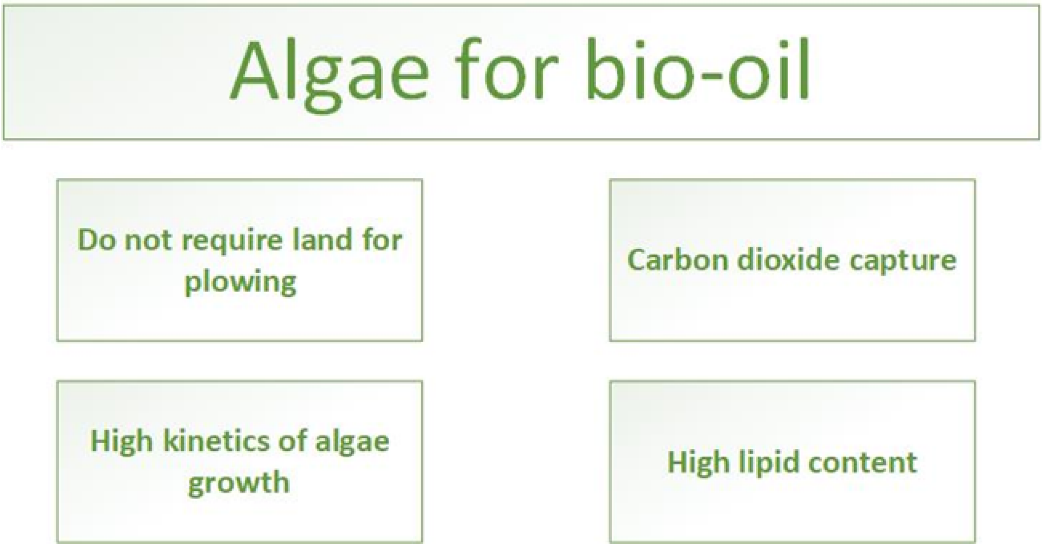

Figure 1. Advantages of producing bio-oil from algae.

Biofuels are a alternative source of unconventional energy in the world. The advantages of biofuels, besides being renewable, are sulfur-free and biodegradable. Biofuels are a low viscosity energy source with a high flash point. Thus, algae biofuels are a promising energy source. It is possible to obtain biofuel from algae during thermochemical treatment.

Thermochemical treatment of algae in comparison with other types of biofuels has the following advantages: high lipid content, which cannot be said about terrestrial crops; no competition with first generation biofuels (agricultural products) due to intensive growth; high absorption of CO_2. Thermochemical processes include five types: pyrolysis, hydrolysis, carbonation, hydrothermal liquefaction, direct combustion. According to Mathimani, Thangavel et al. [33], hydrothermal liquefaction is the most optimal method for producing liquid fuels.

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