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# THE OPPORTUNITY OF DEVELOPING MICROALGAE CULTIVATION TECHNIQUES IN INDONESIA

## [Peluang Pengembangan Teknologi Budidaya Mikroalga di Indonesia]

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**ABSTRACT**

The rate of population growth which is relatively rapidly increasing in Indonesia, will require increased fuel. The depletion of the availability of fossil fuels causes the search for the other natural resources needed to become a renewable energy source. One of the significant changes today is microalgae. The application of the algal aquaculture system has been widely applied in the world. The media used in cultivation also varies, one of which is wastewater. The composition of biodiesel energy in Indonesia is increasing and is starting to become the people's choice. Indonesia, which is rich in natural resources, especially the high biodiversity of microalgae, causes microalgae's potential use to be very high. Many studies report the explosion of algal participation in many parts of Indonesia. Research concerning the cultivation of microalgae has been widely successful in Indonesia. The use of microalgae is already available in the field with domestic water treatment applications. The conversion of microalgae into biodiesel also successfully met the requirements of SNI 04-7182-2006.

**Key words:** *Microalgae cultivation, energy, wastewater treatment, biodiesel*

**ABSTRAK**

Laju jumlah penduduk yang relatif meningkat pesat di Indonesia akan membutuhkan bahan bakar yang bertambah. Menipisnya ketersediaan bahan bakar fosil menyebabkan pencarian akan sumber daya alam yang lain dibutuhkan untuk menjadi sumber energi terbarukan. Salah satu perubahan besar saat ini adalah mikroalga. Penerapan budidaya akuakultur alga sudah banyak diterapkan di dunia. Media yang digunakan dalam budidaya juga beragam, salah satunya adalah air limbah. Komposisi penggunaan energi biodiesel di Indonesia semakin meningkat dan mulai menjadi pilihan masyarakat. Indonesia yang kaya akan sumber daya alam, terutama keanekaragaman hayati mikroalga yang tinggi menyebabkan potensi pemanfaatan mikroalga menjadi sangat tinggi. Banyak penelitian melaporkan ledakan partisipasi alga di banyak tempat di Indonesia. Penelitian mengenai budidaya mikroalga telah berhasil secara luas di Indonesia. Penggunaan mikroalga sudah tersedia di lapangan dengan aplikasi pengolahan air rumah tangga. Konversi mikroalga menjadi biodiesel juga berhasil memenuhi persyaratan SNI 04-7182-2006.

**Kata kunci:** Budidaya mikroalga, energi, pengolahan air limbah, biodiesel

## INTRODUCTION

The reduced reserves of fossil fuels and the increased need for energy encourage efforts to develop raw materials for energy production from renewable sources produced and processed in an environmentally friendly manner (Chaudry *et al.*, 2015). Microalgae culture is the most promising energy source for sustainable biofuel production, including biodiesel, biogas, crude oil, bioethanol, and biohydrogen (Chisti, 2008). Also, microalgae culture can be a high-value bioactive product for nutraceutical and pharmaceutical applications (Adarme-Vega *et al*., 2014; Batista *et al*., 2017). Oil content in algae can reach 77%, potentially being used as biodiesel, which can produce 200 times more oil than other vegetable sources (Sumantri *et al.*, 2018). Even today, algae can become biomaterials, such as bioplastics that can be biodegradable and biocompatible (Markou *et al*., 2013; Gerardo *et al.,* 2015).

Microalgae cultivation can be done in a secure place (closed photobioreactor) (Grima *et al*., 2003) or an open system (open photobioreactor) (Welssman and Goebel 1987). Photobioreactor technology with an anaerobic process produces energy sources in the forms of methane, but anaerobic technology still produces high nutrients that require further processing (Molinuevo-Salces *et al*., 2010). On the other hand, aerobic technology can reduce organic matter and nutrients by mechanically supplying aeration to the system and releasing gases such as CO2 and NH3 or N2O into the atmosphere (Molinuevo-Salces *et al.,* 2010).

Light is part of the electromagnetic radiation spectrum consisting of ultraviolet (UV), visible and infrared (IR) regions limiting factors for growth and the efficiency of microalgae photobioreactors. Light is an essential energy source for microalgae, and its supply in photobioreactors must be adequately related to wavelength, intensity and duration. Solar photon energy can be utilized as a carbon source by photosynthetic microorganisms.

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The solar spectrum at sea level covers wavelengths in the range> 290 nm, while only waves between 400 and 700 nm represent active photosynthetic radiation (Kohen *et al.,* 1995). Most of the radiation from the sun remains unused in the process of photosynthesis. Wavelengths of ultraviolet light range from 100 to 400 nm and are divided into UV-A (315-400 nm), UV-B (280–315 nm), and UV-C (<280 nm) (Holzinger and Lütz 2006; Navntoft *et al.,* 2009). About 90-95% of UV photons, that approach the sun's rays are in the UV-A range, while the rest consists of UV-B radiation (Amrei *et al.,* 2014). Fluorescent and xenon have been used to increase the growth of *Chlorella vulgaris* in various cultivation methods (Mohsenpour *et al.,* 2012; Mohsenpour *et al.,* 2013). *C. vulgaris* biomass productivity increases by up to 20% under xenon lamp radiation (Mohsenpour *et al.,* 2012; Mohsenpour *et al.,* 2013).

Another advantage of using microalgae as biodiesel raw material is in terms of algae breeding. Microalgae reproduce very quickly with a relatively short life cycle, besides microalgae in their infancy utilizing carbon dioxide ($CO_2$), both produced in aquatic bioprocessing systems and free air absorption. Thus, having a positive impact on reducing greenhouse gases and contributing to mitigating global warming and climate change (Kohen *et al.,* 1995).

For this reason, it is necessary to have a review study of the process of algae cultivation along with the opportunity to convert waste energy from microalgae in Indonesia. This paper will discuss the latest research on the cultivation of microalgae globally and then look at the potential and changes in energy use in Indonesia. This review also looks at the current state of research in cultivating microalgae and wastewater treatment in Indonesia. The last is seeing the potential for the extraction of microalgae into biodiesel in Indonesia.

## CURRENT RESEARCH MICROALGAE CULTIVATION

A photobioreactor is a technique for growing microalgae in specific controlled environments. Microalgae can grow very quickly in the right environmental conditions. Most microalgae use light and carbon dioxide ($CO_2$) as energy sources and carbon sources (photoautotrophic organisms). Optimum growth of microalgae requires water temperatures in the range of 15-30°C. Reactors for breeding algae must contain nutrients and minerals that function in cell formation, such as nitrogen, phosphorus, and iron. Table 1 shows the factors affecting microalgae growth.

**Table 1.** Factors affecting microalgae growth (*Faktor yang menyebabkan pertumbuhan mikroalga*)

| No | Environmental Component (*Komponen Lingkungan*) | Condition (*Kondisi*) |
|---|---|---|
| 1 | Abiotic (*Abiotik*) | Sunshine (*SinarMatahari*)<br>Temperature (*Temperatur*)<br>Nutrition (*Nutrisi*)<br>$O_2$,<br>$CO_2$,<br>pH,<br>Salinity (*Salinitas*) |
| 2 | Biotic (*Biotik*) | Bacteria (*Bakteri*),<br>Mushroom (*Jamur*),<br>Virus (*Virus*),<br>Competition with other microalgae (*Kompetisi dengan mikro alga lain*) |
| 3 | Technique (*Teknik*) | Harvesting Methods Such As (*Metode Pemanenan Seperti*) :<br>Giving Substrate (*Pemberian Substrat*)<br>Aeration Time (*Waktu Aerasi*)<br>Reactor Volume (*Volume Reaktor*)<br>Lighting Time (*Waktu Pencahayaan*) |

Source: (Harun *et al.,* 2010)

Microalgae are usually cultivated/grown in open pond systems (Grima *et al.,* 2003) or with closed systems (closed photobioreactors) (Welssman and Goebel 1987) and are given artificial light or sunlight with temperatures of 27–30$^{o}$C and pH 6.5–8. Open systems have problems with contamination and evaporation and inhibit the growth of microalgae. Photobioreactor has a large surface area and volume ratio. The productivity of microalgae using a photobioreactor can reach 13 times the total production using the open raceway pond system (Chisti, 2007). In photobioreactor systems, contaminants and growth parameters such as pH, temperature and carbon dioxide can be appropriately controlled.

**Table 2.** Microalgae cultivation techniques in previous studies (*Teknik budidaya mikroalga pada penelitian-penelitian sebelumnya)*

| No | Cultivation techniques (***Teknik Kultivasi***) | Algae type (***Tipe alga***) | Specific growth rate (***Laju Pertumbuhan Spesifik***) | Ref. |
|---|---|---|---|---|
| 1 | Membrane photobioreactor (MPBR) with a volume of 1000 mL. Lighting in the reactor uses LED lights with red and blue (4:1 ratio). Aeration used is to use pure $CO_2$ (99%). *Membran fotobioreaktor (MPBR) dengan volume 1000 mL. Penerangan pada reactor menggunakan lampu LED dengan warna merah dan biru (rasio 4:1). Aerasi yang digunakan adalahmenggunakan* $CO_2$ *murni (99%).* | *Chlorella vulgaris*, *Scenedesmus obliquus.* | *Chlorella vulgaris* (0.17 $d^{-1}$) dan *Scenedesmus obliquus* (0.15 $d^{-1}$). | (Gao *et al.,* 2016) |
| 2 | Labfors 5 Lux with a volume of 1.8 L with white LED panel. Aeration is done with a debit of 5 L min-1 and 200 mL $min^{-1}$. *Labfors 5 Lux dengan volume 1,8 L dengan panel LED putih. Aerasi dilakukan dengan debit 5 L min-1 dan 200 mL* $min^{-1}$ | *Chlorella sorokiniana* | 0.27 $h^{-1}$ with an initial algal concentration of 0.17 g $L^{-1}$. The final result is 11.34 g $L^{-1}$ with aeration of 5 L min-1 and 9.5 g $L^{-1}$ with aeration of 200 mL $min^{-1}$. (0,27 $jam^{-1}$dengan konsentrasi alga awal 0,17 g $L^{-1}$. Hasil akhir adalah 11,34 g $L^{-1}$dengan aerasi 5 L $min^{-1}$ dan 9,5 g $L^{-1}$dengan aerasi 200 mL $min^{-1}$.) | (Franco 2014) |
| 3 | The photobioreactor used is a 1000L pipe-shaped volume with a plug flow reactor (PFR) system with a length of 240 m. *Fotobioreaktor yang digunakan berbentuk pipa volume 1000L dengan sistem plug flow reactor (PFR) dengan panjang 240 m.* | *Arthrospira platensis* (Spirulina) | 0.12 $d^{-1}$ | (Delrue *et al.,* 2017) |

**Table 2.** Microalgae cultivation techniques in previous studies. *continue*

| No | Cultivation techniques (*Teknik Kultivasi*) | Algae type (*Tipe alga*) | Specific growth rate (*Laju Pertumbuhan Spesifik*) | Ref. |
|---|---|---|---|---|
| 4 | The system used in the form of Internally illuminated photobioreactor (IlPBR) with a volume of 5 L. Variations in the use of LEDs with different wavelengths namely blue (λmax = 450 and 460 nm), green (λmax = 525 nm), red (λmax = 630 and 660 nm), and white (6,500K). *Sistem yang digunakan berupa fotobioreaktor iluminasi internal (IlPBR) dengan volume 5 L. Variasi penggunaan LED dengan panjang gelombang berbeda yaitu biru (λmax = 450 dan 460 nm), hijau (λmax = 525 nm), merah ( maks = 630 dan 660 nm), dan putih (6.500K).* | *Arthrospira platensis* | The highest specific growth rate is found in variations in the use of red LEDs with a value of 0.39 $d^{-1}$ *Laju pertumbuhan spesifik tertinggi terdapat pada variasi penggunaan LED merah dengan nilai 0,39* $d^{-1}$. | (Yim *et al.,* 2016) |
| 5 | Cultivation is carried out in a 2 L volume reactor with UV-A lighting. *Budidaya dilakukan dalam reaktor volume 2 L dengan penerangan UV-A* | *Chlorella* sp. | Specific growth rate calculation results vary from 0.11-0.17 d-1. The final concentration of chlorophyll-a shows the value of 0.36-0.63%. *Hasil perhitungan laju pertumbuhan spesifik bervariasi dari 0,11–0,17 h-1. Konsentrasi akhir klorofil-a menunjukkan nilai 0,36-0,63%* | (Amrei *et al.,* 2014a) |
| 6 | Photobioreactors are used in processing bio industrial wastewater with subtropical temperatures and solar lighting. *Fotobioreaktor digunakan dalam pengolahan air limbah industri bio dengan suhu subtropis dan pencahayaan matahari.* | *Chlorella sorokiniana* | 0.48 $d^{-1}$ | (Podevin *et al.,* 2017) |
| 7 | 4L volume photobioreactors using dimmer LEDs and aeration of $CO_2$ mixture (96: 4 v / v%) continuously with a 0.25 vvm discharge. Fotobioreaktor volume 4L menggunakan LED dimmer dan aerasi campuran $CO_2$ (96:4 v/v%) secara kontinyu dengan debit 0,25 vvm) | *Desmodesmus communis* | 0.64–0.65 $d^{-1}$ | (Vanags *et al.*, 2015) |

**Table 2.** Microalgae cultivation techniques in previous studies. *continue*

| No | Cultivation techniques (*Teknik kultivasi*) | Algae type (*Tipe alga*) | Specific growth rate (*Laju Pertumbuhan spesifik*) | Ref. |
|---|---|---|---|---|
| 8 | Pilot-scale (35 L) panel photobioreactors in a room that uses lights. *Fotobioreaktor panel skala pilot (35 L) di ruangan yang menggunakan lampu* | *Chlorella protothecoides, Chlorella variabilis* | *Chlorella protothecoides*: 0.0022 $h^{-1}$,Chlorella *variabilis*: 0.0030 $h^{-1}$ | (Uyar *et al.,* 2018) |
| 9 | With variations in the N:P ratio (10:1; 15:1; 20:1; and 25:1) in the bubble column (0.2 LPM) photobioreactor. *Dengan variasi N:P rasio (10:1; 15:1; 20:1; dan 25:1) yang berbeda-beda dalam gelembung kolom (0,2 LPM) fotobioreaktor* | *Chlorella* sp. | N: P ratio of 15: 1 produces an SGR of 0.064 $h^{-1}$(N: P ratio of 15:1 produces an SGR of 0.064 $h^{-1}$) | (Bui *et al.,* 2018) |
| 10 | Chlorella vulgaris, cultivated in flat panel photobioreactors and bubble columns with variations (a: −glucose, −$CO_2$); (b: −glucose, + $CO_2$); (c: + glucose, −$CO_2$) and (d: + glucose, + $CO_2$). *Chlorella vulgaris, dibudidayakandalam fotobioreaktor panel datar dan kolom gelembung dengan variasi (a: glukosa, $CO_2$); (b: -glukosa, + $CO_2$); (c: + glukosa, $CO_2$) dan (d: + glukosa, + $CO_2$).* | *Chlorella vulgaris* | Each variation produces a: 0.042 $h^{-1}$, b: 0.070 $h^{-1}$, c: 0.082 $h^{-1}$, and d: 0.083 $h^{-1}$. *Setiap variasi menghasilkan a: 0.042 $h^{-1}$, b: 0.070 $h^{-1}$, c: 0.082 $h^{-1}$, and d: 0.083 $h^{-1}$* | (Subramanian *et al.,* 2016) |
| 11 | The use of Box-Behnken is applied by controlling temperature, the ratio of nitrogen to phosphorus (N: P), and the lighting cycle per day, as a parameter for controlling microalgae growth. *Penggunaan Box-Behnken dilakukan dengan mengontrol suhu, rasio nitrogen terhadap fosfor (N:P), dan siklus pencahayaan per hari, sebagai parameter untuk mengontrol pertumbuhan mikroalga*.) | *Chlorella vulgaris* | A maximum specific growth rate of 0.84 $d^{-1}$ was obtained at 25°C, with N:P 3,4:1, and 24-hour lighting. *Laju pertumbuhan spesifik maksimum 0,84 $d^{-1}$diperoleh pada suhu 25° C, dengan N:P 3,4:1, dan pencahayaan 24 jam.* | (Hossain *et al.,* 2018) |
| 12 | Photobioreactor with assisted by UV-A and UV-B with the air flow rate as much as 1.2 L/min *Foto bioreactor berbantuan UV-A dan UV-B dengan laju aliran udara sebanyak 1,2 L/menit* | *Chlorella* sp., Algae Mix | Specific growth rate of Chlorella sp. and algae mix is 0.025 $h^{-1}$ and 0.027 $h^{-1}$. *Laju pertumbuhan spesifik Chlorella sp. dan campuran alga adalah 0,025 jam $^{-1}$ dan 0,027 jam$^{-1}$.* | (Suryawan and Sofiyah, 2020) |

**Table 2.** Microalgae cultivation techniques in previous studies. *continue*

| No | Cultivation techniques (*Teknik kultivasi*) | Algae type (*Tipe alga*) | Specific growth rate (*Laju pertumbuhan spesifik*) | Ref. |
|---|---|---|---|---|
| 13 | The batch reactors were prepared by adding glucose substrate of 150 mg/L and 24 hours aeration. *Reaktor batch dibuat dengan menambahkan substrat glukosa 150 mg/L dan aerasi 24 jam laju pertumbuhan Chlorella sp. dan campuran alga adalah 0,025 jam$^{-1}$ dan 0,027 jam$^{-1}$* | Algae Mix | 0.0229 $d^{-1}$ | (Afifah *et al.*, 2020) |
| 14 | The batch reactors with 2L of municipal wastewater and flowed air with a flow rate of 1.5 LPM. Reaktor batch dengan 2L air limbahkota dan udaramengalirdenganlajualiran 1,5 LPM. | *Spirulina platensis*, *Nannochloropsis oculata* | *Spirulina platensis* 0.0279 $h^{-1}$ and *Nannochloropsis oculate showed* 0.0282 $h^{-1}$. *Spirulina platensis 0,0279 $h^{-1}$ dan Nannochloropsis oculate menunjukkan 0,0282 $h^{-1}$* | (Sofiyah and Suryawan, 2021) |

According to Hanif *et al.,* (2016), microalgae can be processed into more valuable products with a combination of environmentally friendly techniques. Valuable products are as follows:

1. As an absorber of $CO_2$ emissions in treating exhaust gases (Wang *et al.,* 2008; Hanifzadeh *et al.,* 2012; Yen *et al.,* 2015)
2. Biomaterials such as bioplastics that can be biodegradable and biocompatible (Markou and Nerantzis 2013; Gerardo *et al.,* 2015)
3. Degradation of pollutant levels in waters such as nutrients (Caporgno *et al.,* 2015; Delgadillo-Mirquez *et al.,* 2016; Prandini *et al.,* 2016; Afifah et al., 2019) organicmatter (Matamoros *et al.,* 2015; Usha *et al.,* 2016; Mujtaba *et al.,* 2017), heavy metals (Kumar *et al.,* 2015; Shahid *et al.,* 2019), and radioactive waste (Fukuda *et al.,* 2013).
4. Microalgae can be extracted to get antioxidants that are good for health (Fithriani *et al.,* 2015).
5. Microalgae can be used as animal feed and aquaculture (Vigani *et al.,* 2015).
6. Microalgae culture is the most promising source of energy for sustainable biofuel production such as biodiesel, biogas, crude oil, bioethanol and biohydrogen (Chisti, 2008)

Microalgae can set aside a high nutrient content in wastewater because algae uptake these nutrients for survival. Nutrients that are altered by algae are macronutrients, namely nitrogen and phosphate. According to Duborow *et al.* (1997), algae utilize ammonium availability in growth media, however, according to Flynn (1990) algae that grow in environments with excess ammonium can suppress their ability to use other nitrogen sources such as nitrates. Photosynthesis process occurs as follows:

$$106CO_2 + 236H_2O + 16\ NH_4^+ + HPO^4_2 \rightarrow C_{106}H_{181}O_{45}N_{16}P + 118O_2 + 14H^+ + 171H_2O \quad (1)$$

Biomass from microalgae contains 50% carbon per dry weight, and the carbon content in microalgae is obtained from carbon dioxide in the air (Sanchez, 2003). To produce 100 tons of biomass, carbon dioxide must be supplied continuously to guarantee the amount and quality of microalgae produced (Molina, 1998). Complex carbohydrates such as corn, sago, and wheat flour are more slowly metabolized (digested) than alcohol and sugar. However, the advantage of using complex carbohydrates is that they can provide particles attached to bacteria. These particles will also facilitate the process of releasing organic carbon. Complex carbohydrates require bacterial enzymes that are suitable in the process of decomposition. Other bacteria and microorganisms use carbohydrates (sugar, starch, and cellulose) as food to get energy and grow through new cells' formation (Avnimelech *et al*., 1994). The process can be seen in the following equation

$$C_{organic} \rightarrow CO_2 + \text{Energy} + \text{C-assimilation in microbial cells} \quad (2)$$

Microalgae need enough nutrients and carbon dioxide to carry out photosynthesis. To optimize algae growth, the required C: N: P ratio is 100: 5: 1 (Fulazzaky and Gany, 2009). The other study reported that the typical ratio for algae growth is 106: 16: 1. This ratio is commonly called the Redfield Ratio (Baird *et al.,* 2004). The application of fertilizer at night must be stopped. However, biomass must still be circulated to avoid the accumulation of biomass on the water's surface

## OPPORTUNITIES

### Energy status in Indonesia

The reduced potential of fossil energy, especially oil and gas, has encouraged the Government to make renewable energy a top priority for maintaining energy security and independence, given the enormous potential for renewable energy to become a mainstay in the supply of national energy the future. The potential for renewable energy in Indonesia is currently not fully utilized. One of the regulations governing the development of renewable energy in the future is PP No. 79 of 2014 concerning National Energy Policy. The composition of energy use from biodiesel starts to increase from year to year (Figure 1). At the same time, biogas production began growing in 2018.

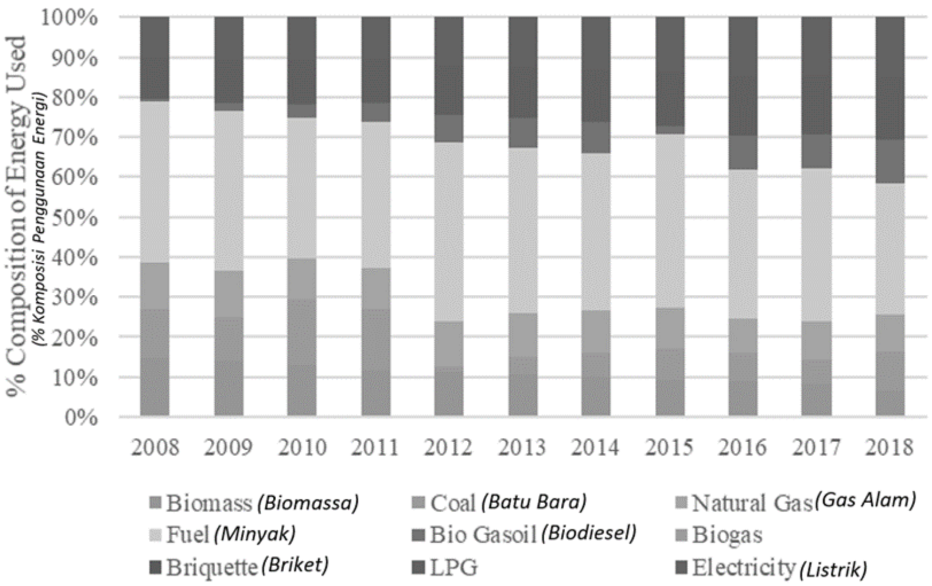


**Figure 1.** Changes in the composition of energy use in Indonesia (*Perubahan komposisi energi yang digunakan di Indonesia)* (ESDM, 2019)

Not all oil uses can be replaced with other energy, especially renewable energy so that future oil demand will continue to increase in line with economic and population growth. The share of renewable energy (water, geothermal, biofuel, wind, solar, biogas) also increased from 8% to 16% in 2025 and fell to 13% in 2050 (ESDM, 2019). New renewable energy that will grow rapidly is liquid fuels such as fuel and renewable energy generation such as geothermal, water and biomass (including solid waste and wastewater). During the 2015-2050 period, demand for renewable energy rose 6.4% per year (ESDM, 2019). Figure 2 shows that the energy consumption of biomass in Indonesia is currently starting to decrease and increase fuel consumption from biodiesel. Therefore, it is essential in the search for new renewable energy that produces biodiesel. This time is an opportunity to convert biomass in the form of algae to biodiesel.

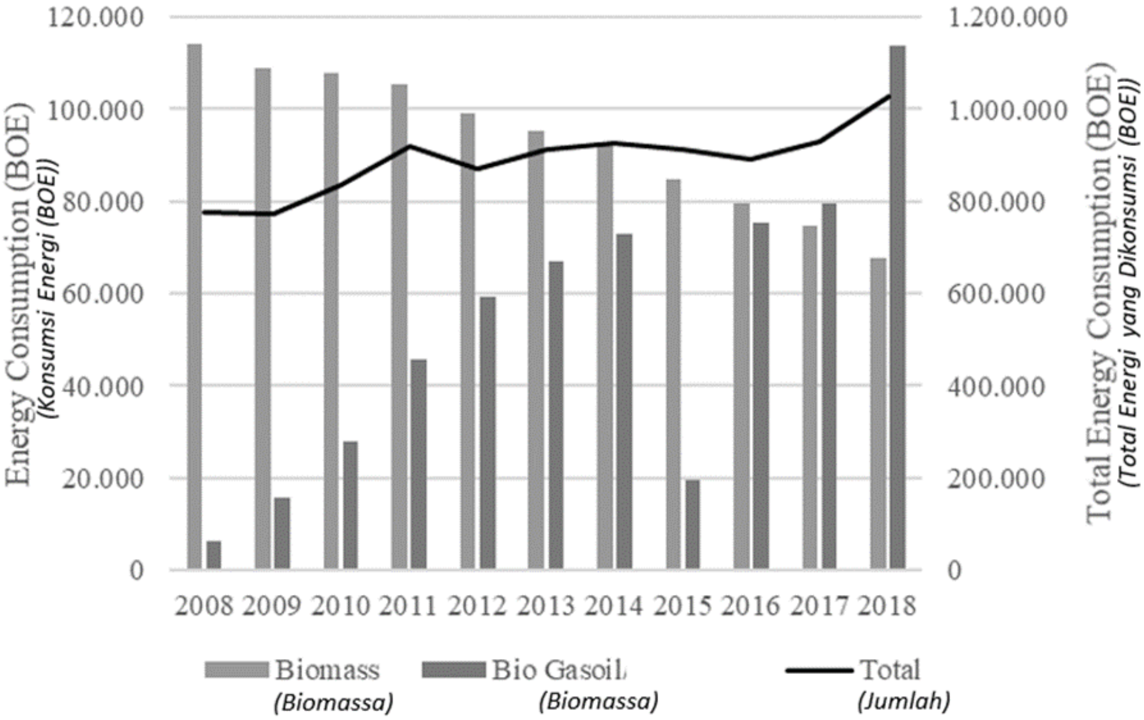


**Figure 2.** Rate of energy use from biomass and biodiesel, and total energy use in Indonesia (including fuel, electricity, coal, and gas) (ESDM, 2019) [*Tingkat penggunaan energi dari biomassa dan biodiesel, dan total penggunaan energi di Indonesia (termasuk bahan bakar, listrik, batu bara, dan gas)* (*ESDM, 2019*) *]*

**Microalgae growth in Indonesia**

Indonesia is a tropical country that is crossed by the equator and has only two seasons, the dry season and the rainy season. This condition makes photosynthesis plants, including microalgae, flourish because they get enough SUN rays, which is an average of 12 hours per day for the area. Besides that, the sea's potential in Indonesia makes the potential of this microalga even greater if cultivated around the coast. Batten *et al.* (2011) explained that Indonesia is the third country in the APEC member that has considerable potential in microalgae production. Regions of countries with temperatures above 150°C tend to be suitable for microalgae production (Van Harmelen and Oonk, 2006) (Figure 3).

Microalgae can grow in low-quality waters, such as agricultural runoff or domestic liquid waste, industrial or agricultural wastewater containing sources of nitrogen, phosphorus, and micro-nutrients. Due to the availability of abundant nutrients in the waters, microalgae will flourish until microalgae bloom. This phenomenon is undesirable because the sun's penetration into the water's surface will be hampered. Thus the life under the water's surface will be disrupted, resulting in an imbalance of the ecosystem. On the other hand, this phenomenon can provide economic incentives to the environment by reducing water and chemical treatment costs needed to create microalgae growth media and play a role in wastewater treatment.

As a potential source of national food security, microalgae should continue to be echoed to in-crease domestic nutritional needs. At present, the bulk price for *Spirulina platensis* is around Rp. 200,000-350,000/kg for imported products (Azimatun, 2014). This requires a special step in reducing the cost of producing food-grade microalgae so that prices are lower and consumed by the public. Indonesian region with a large coastline may be many microalgae industries that grow along the coast or areas with barren land that cannot be planted with productive plants, to be used as microalgae aquaculture ponds.

***Sumatra Island region***

In West Sumatra, precisely in Lake Maninjau, there are 121 species of phytoplankton belonging to the *Phylum Chlorophyta* (74 species), *Cyanophyta* (23 species), *Pyrrhophyta* (7 species) and *Euglenophyta* (4 species) (Sulastri *et al*. 2019). The results of other studies in the Lampung Bay region indicate the presence of several phytoplankton species in waters that have the potential to cause HAB, namely the class of toxin producer and red tide maker (Barokah *et al.,* 2017). In the east season phytoplankton identified and potentially causing Harmful Algae Bloom HAB are *Amphora* sp., *Nitzchia* sp., *Ceratium* sp., *Dynophisis* sp., *Gymnodinium* sp., and *Nocticulla scintillans* (Barokah et al. 2017). While in the west season are *Amphora* sp., *Nitzchia* sp. *Pseudonitzchia* sp., *Alexadrium* sp., *Ceratium* sp., *Dhynophisis* sp., *Gambirdiscus toxicus*, *Gymnodinium* sp., *Nocticula scintillans*, *Procentrum* sp., *Pyrodinium Bahamas*, and *Perinidium* sp. (Barokah *et al.,* 2017).

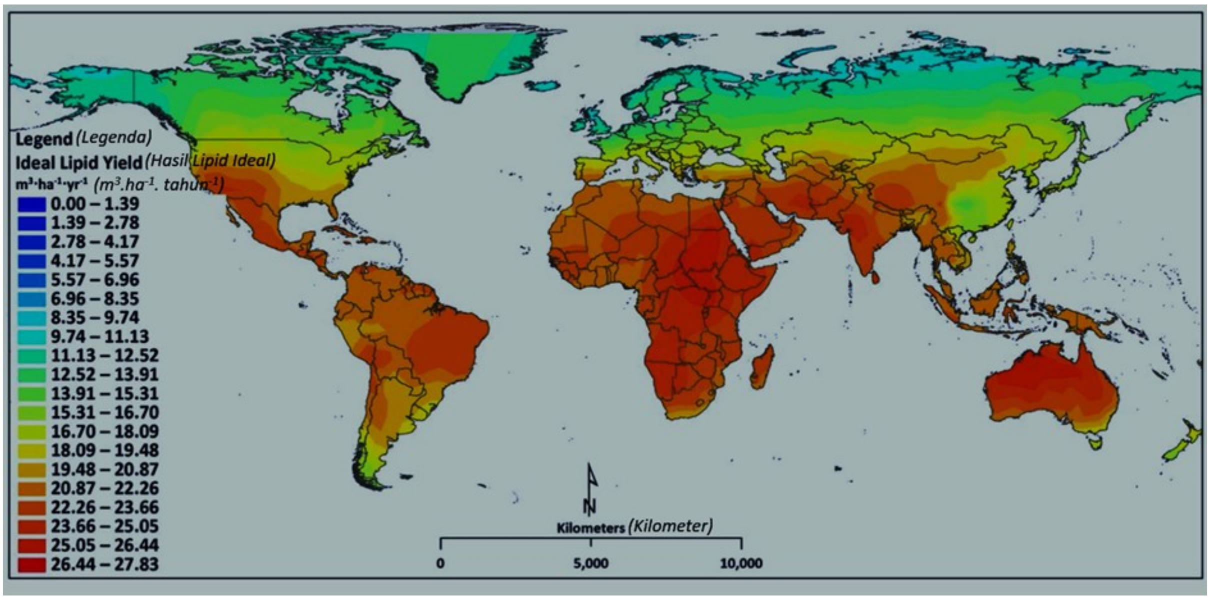


**Figure 3.** Potential of lipid production in the world (*Potensi produksi lipid di dunia)* Moody *et al.,* 2014)

***Java Island Region***

In the areas of North Jakarta, South Jakarta, East Jakarta, and Depok showing that there are at least 11 generations of Cyanobacteria planktonic found in these waters, namely *Aphanizomenon, Arthrospira, Borzia, Chroococcus, Merismopedia, Mycrocystis, Nostoc, Oscillatoria, Planktothrix, Spirulina*, and *Synechococcus* (Prihantini *et al*., 2006). Microalgae concentration in Jakarta Bay during first inter-monsoon and east monsoon ranging from $40.90 x 10^6$–$1699.10 \times 10^6$ cells/$m^3$. This is also possible because of the high nitrogen/ phosphate (N/P) ratio which reaches 11–110 (Sidabutar *et al.,* 2016).

Plumbon river is located in the village of Mangkang Kulon, Tugu District, Semarang City which several sources of pollutants enter the waters of the river. Pollutants including from home industry wastes, such as the tofu and fish smoke industry, droplets/ship fuel spills that cross the Plumbon river. The household wastewater found 39 types of microalgae consisting of four classes, namely Baccilariophyceae, Chlorophyceae, Cyanophyceae and Euglenaphyceae. Microalgae, which have the highest abundance, are from the genus *Pseudonitzschi* with a total abundance of 5,267 ind/L and Navicul with a total abundance of 1,663 ind/L (Aprianti *et al.,* 2015).

In the Lamongan Coastal region, particularly in the Brondong sub-district area, there are various industrial activities, including the activities of the processing industry of fisheries and fishing ports. Effluent from the fish processing industry and fishery port activities will increase aquatic nutrients, including nitrate and phosphate (Choirun *et al.,* 2015). The number of algae at high tide was 1,537,059 cells/L with a HAB phytoplankton ratio at the high tide of 2% with a total abundance of 33,555 cells/L (Choirun *et al.,* 2015).

***Nusa Tenggara Region***

Microalgae characterized by chlorophyll-a, chlorophyll-b and carotenoids were mostly contained by the *Chaetoceros gracilis.* Species in the Bali strait region (Fauziah *et al.,* 2019). On the island of Lombok in the waters of the river estuary Pelangan Pelangan Village Sekotong District West Lombok Regency identified 85 species of microalgae with the highest number of species (24 species) examples, namely *Chlorococcum humicola, Coscinodisccus lacustris, Thalassiothrix fruenfeldii*, and *Rhizosolenia* sp. (Astuti *et al.,* 2017).

**Cultivation and potential wastewater treatment**

Previous research on algae cultivation has been carried out on *Chroococcus* sp. and *Pseudanabaena* sp. produced higher yields than other marine cyanobacteria cultures, yielding biomass yields very low (Priatni *et al.,* 2016). Seawater cultivation has also been carried out on *Chaetoceros* sp. and *Spirulina sp,* resulting in an average growth rate of $0.197x10^5$ cells/ml/day and $0.156x10^5$ cells/ml/day (Diansyah 2018). Other results by cultivation using seawater with microalgae *Nannochloropsis* sp. yield 74,415 ind/ml (Kawaroe *et al.,* 2015).

The value of biomass productivity depends on growth media. For example, the treatment of microalgae on AF6 media is 0.0340 gr/L/day lower than that of leachate media, which is 0.0570 gr/L/day (Prinanda *et al.,* 2017). In the growth of tofu wastewater media with *Chlorella pyrenoidosa* microalgae, it has a density of 1,200,000 cells/mL, *Spirulina plantesis* has a density of 1,170,000 cells/mL (Simamora *et al.,* 2017). *Botalococcus braunii* microalgae cultivation experiments on clean water media were carried out with different room conditions showing the highest biomass ranging from 7.33 log cells/mL in the indoor system and 7.02 log cells/mL in the outdoor system (Susilowati and Amini, 2018). Giving flow rate in the form of nitrogen to *Chlorella* sp. produce optimum biomass growth of 60% (Senjaya *et al.,* 2017).

In the palm oil wastewater media, Spirogyra sp.'s growth can reach 0.034 grams/day (Baihaqi *et al.,* 2018). *Chlorella pyrenoidosa* and *C. vulgaris* cultivation in livestock wastewater. This treatment resulted in cell density, 5.181 X 106 cells/ ml, with a specific growth rate of 0.190 d-1 and a doubling time of 3.65 d-1 and 3.286 X 106 cells per millilitre, a specific growth rate of 1.348 d-1, and a doubling time of 0.514 d-1 (Azhar *et al*., 2017). The use of algae in wastewater treatment can be found in the Nusa Dua area, Bali. The wastewater system uses a waste stabilization pond (WSP) system with high nutrients. However, the high nutrient can cause algae bloom, which reduces water quality (Suryawan *et al*., 2019; Apritama *et al*., 2020; Fadhilah *et al*., 2020). The results of this study showed that there were 37 types of algae with a total suspended solids (TSS) of 611 mg/L (Pratiwi *et al*. 2019). This is undoubtedly one of the opportunities for the utilization of microalgae into energy.

**Figure 4.** Potential of algal production in wastewater treatment with microalgae in Indonesia; WSP condition observed by Pratiwi *et al.,* 2019 (left), WSP condition observed by authors (right). [*Potensi produksi alga dalam pengolahan air limbah dengan mikroalga di Indonesia; Kondisi WSP diamati oleh Pratiwi et al., 2019 (kiri), Kondisi WSP diamati oleh penulis (kanan)]*

**Potential biodiesel**

In wastewater treatment with algae isolation with the species *Chlorella* sp., *Synedra* sp., and *Navicula* sp., they can produce 21.20%, 20.30%, and 27.20%, respectively, of the total lipids over their biomass which are then converted to biodiesel (Saputro *et al.,* 2019). With seawater media with the cultivation of *Chaetoceros* sp. produce 14.89% oil and *Spirulina* sp. cultivation. 18.11% (Kawaroe, 2015). The addition of aeration with nitrogen produced a lipid of 16.83% (Susilowati and Amini, 2018). The use of wastewater as a growth medium for microalgae has the potential to produce greater lipids. Cultivation of *Nannochloropsis* sp. optimum in liquid tofu wastewater produces lipids as much as 34.25% (Widayat and Hadiyanto, 2015). Microalgae extraction was also carried out on *Nannochloropsis occulata*, which contained phytosterols with an abundance of 91.96% consisting of campesterol, stigmasterol, and βsitosterol with the removal of 23.02%; 29.04%, and 39.80% (Jati *et al.,* 2019). *Chlorella* sp. cultivation with liquid tofu wastewater media also produced a reasonably large lipid of 0.5160 gram/ Liter (Harahap et al., 2013). Direct transesterification of microalgae *Chlorella* sp. has also been carried out with microwave radiation-producing oil characteristics, including the viscosity of 10.281 cSt, with a density of 0.9077 g ml-1, and a refractive index of 1.46 (Faisal et al., 2015). Gas Chromatography-Mass Spectrometer (GC-MS) results of *Chlorella* sp. products showed that the composition of methyl ester consisted of methyl oleate (64.68%), methyl palmitate (19.63%), and methyl linoleate (7.81%) (Faisal *et al*., 2015).

The quality of commercial biodiesel refers to the national standards of SNI 04-7182-2006 with parameters that must be met, among others, the stability of biodiesel and cetane numbers, where these characteristics are influenced by the composition of vegetable oil fatty acids used. Five species of microalgae cultivation (*Nannochloropsis* sp., *Spirulina* sp., *Chlorela* sp., *Dunaliela* sp., and *Tetraselmis* sp.), then the oil content was extracted and analyzed, the test results had methyl ester saturated content of palmitic acid (C16: 0), which is around 40%, except forTetraselmis sp. which is only around 25% (Saadudin *et al.,* 2016). The diversity of microalgae species from Lake Kerinci waters in Jambi was cultivated, resulting in microalgae isolates. Biodiesel sources with high lipid and saturated fatty acids (Hernandi *et al.,* 2019).

## CONCLUSION

The application of microalgae cultivation technology is essential to do especially in developing countries like Indonesia. Prevention of algae bloom can be done by utilizing the microalgae through the energy conversion process. Microalgae have also been applied in the field in the wastewater treatment process. Sustainable product from microalgae development, it is necessary to use microalgae into biodiesel. Based on a review of the research results on the use of algae into biodiesel has met national standards. The important point is the application of converting microalgae to biodiesel on a large scale.

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