Jurnal Rekayasa

by I Wayan Koko Suryawan

Cultivation of Spirulina platensis and Nannochloropsis oculata for nutrient removal from municipal wastewater

Abstract

Air limbah domestik mengandung nutrient rata-rata ammonia-N (NH_3-N) dan total phospate (PO_4^{3-}-P) yang tinggi. Kandungan nutrient tersebut berpotensi menyebabkan eutropikasi di badan air. Mencegah eutropikasi tersebut maka perlu dilakukan pengolahan terhadap air limbah domestik. Saat ini diperlukan teknolgoi pengolahan yang bermanfaat terhadap peningkatan kualitas air limbah hasil olahan dan byproduct yang sedikit. Salah satu teknologi tersebut adalah pengolahan dengan sistim mikroalga, dimana alga tersebut dapat dimanfaatkan menjadi biodiesl. Dua jenis mikroalga yang berpotensi menghasilkan biodiesl yaitu *Spirulina platensis* dan *Nannochloropsis oculate*. Kultivasi terhadap kedua jenis mikroalga tersebut dilakukan pada media air limbah domestic Kota Jakarta dengan memberikan pencahayaan 24 jam dengan UV-A dan UV-B. Laju pertumbuhan spesifik *Spirulina platensis* dan *Nannochloropsis oculate* tidak jauh berbeda yaitu 0,0279 h-1 dan 0,0282 h-1. Masing-masing mikroalga *Spirulina platensis* dan *Nannochloropsis oculate* dapat mereduksi nutrient NH3-N sebesar 82% dan 80%, sedangkan PO_4^{3-}-P sebesar 65.2% dan 63.7%. Nilai pH selama proses pengolahan menunjukkan dalam rentang pH normal. Total dissolved solid (TDS) dalam proses pengolahan juga menurun dalam rentang waktu 48 jam.

Domestic wastewater contains a high average nutrient ammonia-N (NH_3-N) and total phosphate (PO_4^{3-}-P). This nutrient content has the potential to cause eutropication in water bodies. To prevent this eutropication, it is necessary to treat domestic wastewater. Currently, processing technology is needed that is useful for improving the quality of processed wastewater and a small amount of byproduct. One of these technologies is processing with a microalgae system, where the algae can be used to become biodiesel. Two types of microalgae that have the potential to produce biodiesel are *Spirulina platensis* and *Nannochloropsis oculate*. The cultivation of the two types of microalgae was carried out in the domestic wastewater media of Jakarta City by providing 24-hour lighting with UV-A and UV-B. The specific growth rates of *Spirulina platensis* and *Nannochloropsis oculate* were not much different, namely 0.0279 h^{-1} and 0.0282 h^{-1}. The microalgae *Spirulina platensis* and *Nannochloropsis oculate* respectively reduced NH_3-N nutrients by 82% and 80%, while $PO_4{}^3$-P was 65.2% and 63.7%. The pH value during processing shows in the normal pH range. Total dissolved solids (TDS) in the processing process also decreased in a span of 48 hours.

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Keywords

Kata Kunci: wastewater, nutrient, algae, NH_3-N, PO_4^{3-}-P

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INTRODUCTION

The amount of wastewater discharged will always increase with the increase in population and activities. If the amount of water discharged exceeds nature's ability to accept it, it will damage the environment. If environmental damage occurs, it will disturb the health level of humans who live in that environment (Suryawan & Sofiyah, 2020; Apritama et al., 2020). One of the contents in domestic wastewater that often causes problems in water bodies is nutrients in the form of NH3-N and PO_4^{3-}-P. Nutrient Microalgae grow fast in waters with high organic and inorganic nitrogen, because these compounds are limited substrates in microalgae.

In this study, *Spirulina platensis* and *Nannochloropsis oculate* microalgae were used to treat domestic wastewater. Microalgae *Spirulina platensis* and is one of the green-blue algae that has been widely researched for its nutritional content, both in the food, health and aquaculture industries (Colla et al., 2015). *Nannochloropsis oculate* is a type of single-celled microalgae that is included in one of the Eustigmatophyceae classes, which has enormous potential for raw material for triglyceride production, because this microalgae is very easy to cultivate continuously with a short harvest period (Widianingsih, et al., 2011).

Microalgae *Spirulina platensis* not only has a high protein content but also contains amino acids, lipids, fatty acids, carbohydrates, vitamins, minerals, and pigments (Bezerra, et al., 2012). Meanwhile, Nannochloropsis oculata has a fairly large oil content, namely 31-68% (Chisti, 2007). Several studies have also shown that *Spirulina platensis* has the potential to be a raw material in the manufacture of renewable alternative fuels. *Spirulina platensis* has the potential to be used as a raw material for making biodiesel even though the lipid content in *Spirulina platensis* is not as high as in other microalgae because of the high growth rate of *Spirulina platensis* cells (Sumprasit, et al., 2017). Based on this description, the aim of this study was to determine the growth and rate of specific biomass of *Spirulina platensis* and *Nannochloropsis oculate*. The removal efficiency of NH_3-N and PO_4^{3-}-P was also measured to determine the performance of microalgae in removing nutrients.

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METHOD

Municipal Wastewater

The wastewater used in this research is wastewater taken from the influent of wastewater treatment in a residential area in Jakarta. The characteristics of wastewater still do not meet the quality standards for wastewater in Jakarta, where NH_3-N still has a concentration above 10 mg/L. Phosphate content in wastewater also does not meet quality standards, which is still above 5 mg/L.

Microalgae Seeds

Spirulina platensis and *Nannochloropsis oculate* seeds were obtained from algae farmers in Jakarta. These microalgae are then grown in the Integrated Chemical Laboratory at Pertamina University. This is done to adapt the algae to new environmental conditions. The growth rate of microalgae biomass in the log growth phase can be expressed as equation 1.

$$\frac{dX}{dt} = \mu \cdot X \qquad (1)$$

Where X = biomass concentration (mg/L) and μ is the specific growth rate (growth rate per biomass unit, units/day).

Experiment set-up

The reactor used in microalgae growth is a glass reactor with a volume of 3 L with a medium of 2 L of waste water (Figure 1). Then the reactor flowed air with a flow rate of 1.5 LPM. During the processing process, lighting was also carried out with UV-A and UV-B lamps.

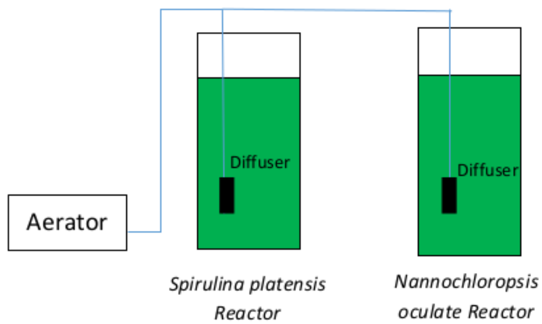


Figure 1. Experiment set-up in microalgae cultivation of *Spirulina platensis* and *Nannochloropsis oculate* in domestic wastewater media

Sampling was carried out within a period of 48 hours with a time period of 0; 4; 8; 12; 24; and 48 hours. Sampling was carried out with a volume of 200 mL for testing for total suspended solid (TSS), Ammonia-N (NH_3-N), Total Phospate (PO_4^{3-}-P). The pH value and total dissolved solid (TDS) were measured as control parameters. Table 1 shows the test method for each parameter.

Tabel 1. Test method of each parameter

No	Parameters	Test method
1	TSS	Gravimetric
2	NH_3-N	Phenate
3	PO_4^{3-}-P	Acid Persulfate Digestion
4	TDS	Gravimetric

RESULTS

Biomass Production

The calculation of the specific growth rates of *Spirulina platensis* and *Nannochloropsis oculate* with equation 1 (Figure 1) showed an increase at 48 hours cultivation. *Spirulina platensis* showed a specific growth rate of 0.0279 h^{-1}, while *Nannochloropsis oculate* showed a specific growth rate of 0.0282 h^{-1}.

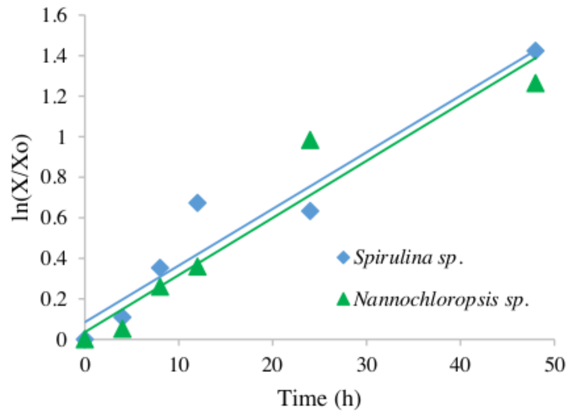


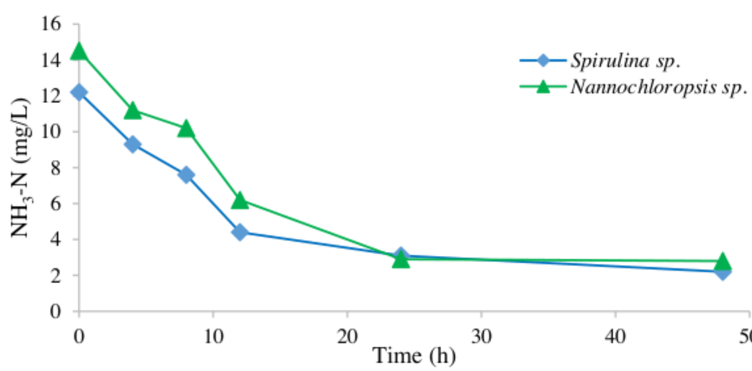
Figure 2. Graph of growth equation for microalgae microalgae *Spirulina platensis* and *Nannochloropsis oculate* in domestic wastewater media

Cultivation results of *Spirulina platensis* vary widely from low to high values. *Spirulina platensis* cultivated in 0.5 dm^3 Erlenmeyer flasks only produced a specific growth rate value of 0.044 day^{-1} (Lodi, Binaghi, Solisio, Converti, & Del Borghi, 2003). Better results were found in the cultivation of *Spirulina platensis* using transparent jars media, polyethylene bags and raceway ponds with specific growth rate values of 0.32, 0.21 and 0.20 day^{-1}, respectively (Göksan, et al., 2007). Cultivation of *Spirulina platensis* in tofu wastewater media also produces a specific growth rate which is quite high, namely 0.15-0.29 day^{-1} (Hadiyanto, 2018).

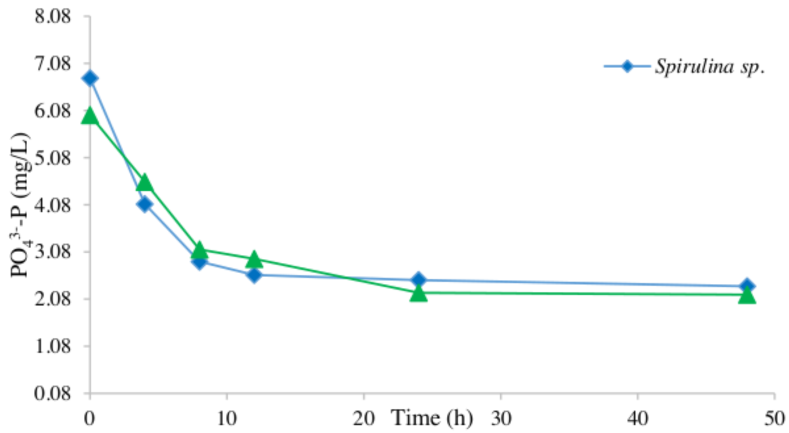
The growth results of Nannochloropsis oculata in this study were close to the highest specific growth rate (μmax) of 0.037 h^{-1} (Ra, Kang, mJung, Jeong, & Kim, 2016). Cultivation techniques (Franco, 2014) with microalgae Chlorella sorokiniana showed values of 0.085 and 0.053 h^{-1} using LED Flat Panel lights. In a research on microalgae cultivation with a pilot scale with a volume of 35 L using Chlorella protothecoides and Chlorella variabilis showed values of 0.0022 h^{-1} and 0.003 h^{-1} (Uyar, et al., 2018).

Nutrient Removal

The removal of nutrient ammonia-N and phosphate almost shows the similarity between *Spirulina platensis* and *Nannochloropsis oculate*. It can be seen that the initial Ammonia-N content in each treatment between *Spirulina platensis* and *Nannochloropsis oculate*, namely 12 mg/L and 14 mg/L (Figure 2).



a. NH3-N degradation oleh *Spirulina platensis* dan *Nannochloropsis oculate*



b. PO_4^{3-}-P degradation oleh *Spirulina platensis* dan *Nannochloropsis*

Figure 3. Nutrient NH3-N (a) and PO_4^{3-}-P (b) removal in domestic wastewater by *Spirulina platensis* and *Nannochloropsis oculate*

At the start of processing from 4 hours to 12 hours of processing *Nannochloropsis oculate* was seen to be faster removing NH_3-N, at 24 hours and 48 hours of processing, NH3-N removal was almost the same. The removal efficiency of NH_3-N was 82% and 80%, respectively. Higher yields can be obtained by another study with a residence time of 10 days, NH_3-N removal by *Spirulina platensis* was 97.8% (Kun, Zhi, & Wenjie, 2010). The use of microalgae Nannochloropsis sp in treating rubber industry wastewater can reduce the NH_3-N content by 98% (Utomo, Nawansih, & Komalasari, 2015).

The removal of phosphate compounds in the form of PO_4^{3-}-P also showed a removal that was almost the same as NH_3-N where the removal of phosphate was seen to be faster than that of NH_3-N. The phosphate removal efficiency for *Spirulina platensis* and *Nannochloropsis oculate* were 65.2% and 63.7%, respectively. *Spirulina platensis* that was cultivated by previous researchers only resulted in a 64.5% reduction (Kun, et al., 2010). The manufacture of Wastewater Treatment Plant (WWTP) based on microalgae biofilm with the best detention time of 24 hours showed a removal of 80% ammonia and 60.38% Phosphate (Anugroho, et al., 2019). The use of microalgae media is very effective in removing nutrients, especially on NH_3-N compared to activated sludge which only removes 17.9% of NH3-N (Suryawan, et al., 2019). These results indicate that the efficiency of nutrient removal is highly dependent on environmental conditions and the microalgae cultivation technique. Phosphate compounds as macro compounds are useful for microalgae for cell growth, for energy transformation, for photosynthesis, and for the formation of chlorophyll (Kanibawa, 2001).

Control Parameters

To support the processing of NH3-N and PO_4^{3-}-P, the TDS value was measured (Figure 4). A decrease in the TDS value can be seen to occur drastically at the beginning of processing, namely at 4 hours and 8 hours of processing. Meanwhile, at 12 hours, 24 hours, and 48 hours it has shown a stable value. The pH value in the treatment did not appear to change significantly (Figure 4).

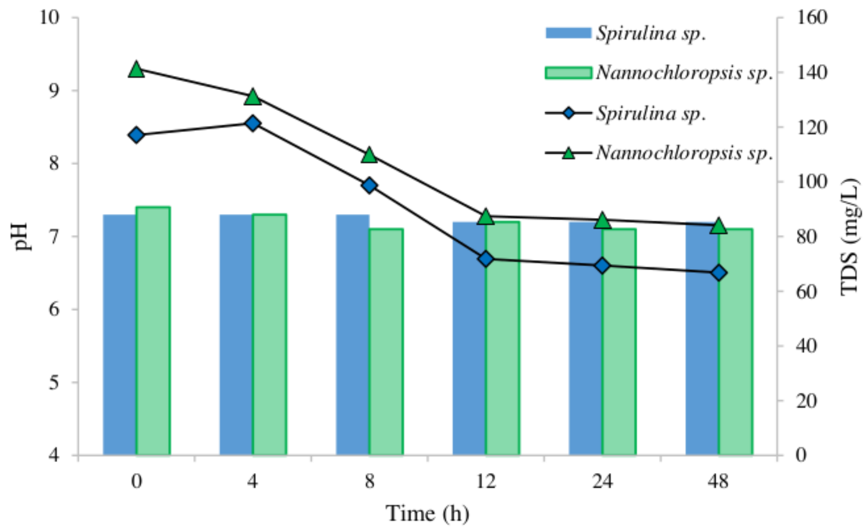


Figure 4. Changes in TDS and pH values in domestic wastewater treatment by *Spirulina platensis* and *Nannochloropsis oculate*

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CONCLUSIONS

The specific growth rates of microalgae cultivated by *Spirulina platensis* and *Nannochloropsis oculate* were 0.0279 h-1 and 0.0282 h-1, respectively. The NH_3-N content can be reduced by 82% and 80%. The PO_4^{3-}-P parameter can be reduced higher, namely 65.2% and 63.7%.

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