ANALYSIS OF REDUCING CO_2 EMISSIONS USING SPIRULINA MICROALGAE

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Abstract

Greenhouse Gases (GHG) consists of various types of gases that are produced either naturally from the environment or from the activities of living things, some examples of the dominant GHGs are water vapor, carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NOx) and Sulfur Oxide (SOx), the largest contributors to GHG emissions are in the Energy sector, amounting to 175.62 million tons of CO_2. Microalgae are the most primitive plants, can grow in low water quality with the availability of adequate nutrients and sunlight. The amount of CO_2 that can be absorbed by 1 kg of dry spirulina is 1.83 kg of CO_2. In addition, Spirulina Platensis can tolerate gas content of SOx, NOx and CO_2 whose concentrations are <12%. This study aims to determine the process of utilizing CO_2 gas emissions from power plant for the cultivation of Spirulina Platensis microalgae at PT. Indonesia Power UPJP Perak Grati. Based on the research results, the average emission load value generated from power plant, especially HRSG 1.1, is 10,403.31 tons CO_2/ month on average. The temperature factor has a significant correlation with the growth of microalgae cells with an inverse correlation. Based on the tests carried out to determine the relationship between changes in the flow rate of CO_2 in microalgae cultivation ponds to the growth of microalgae cells, it was found that the addition of CO_2 in the cultivation pond with a flow rate of 1 L/ minute had a greater effect than other treatments. The amount of CO_2 absorption by microalgae installations with a flow rate variation of 1 liter CO_2/ minute is able to absorb 0.2766 tons of CO_2/ month, or is only capable of <1% of the average emission load of HRSG 1.1 per month.

Keywords: *CO_2, Microalgae Spirulina Platensis, Power plant emissions, Emission Loads*

Introduction

Currently the issue of Global Warming has become an issue around the world, which is one of the causes of global warming is the occurrence of the greenhouse effect on the earth's atmosphere, which results in the effect of heat reflected on the earth's surface trapped by the gases in the atmosphere layer, as a result the heat will be reflected back to the earth's surface so that the earth's surface temperature increases (Hairiah, 2007). Greenhouse Gases (GHG) consists of Carbon Dioxide (CO_2), Methane (CH_4), Nitrogen Oxide (NOx) and Sulfur Oxide (SOx). Based on GHG emissions inventory data in the Energy Sector from the Ministry of Energy and Mineral Resources, the total GHG emissions produced in Indonesia in 2015 amounted to 261.89 million tons of CO_2 with an average increase of 2.43% per year. The biggest contributor to GHG emissions is in the Energy sector, amounting to 175.62 million tons of CO_2.

PT. Indonesia Power Generation Unit and Pembangkitan Perak Grati are committed to becoming a Trusted Energy company that is friendly to the environment. One of its applications is by making efforts to reduce CO_2

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emissions from power plant activities, namely utilizing CO_2 from exhaust gas emissions from the generation process, especially power plan. CO_2 gas is a gas produced from the combustion process of fossil fuels. In this case the emissions are generated from the Gas and Steam Power Plant (GSPP), which in the process uses gas as the fuel. The amount of CO_2 gas produced from gas fuel is 12% (Pusdatin ESDM, 2016).

Therefore it is necessary to reduce CO_2 gas emissions, one of which is by mitigating CO_2. CO_2 in nature is the main source in the process of plant photosynthesis, one of which is the Microalgae Spirulina Platensis (Istiyanie, 2011).

Microalgae are the most primitive plants, with cellular size and commonly known as phytoplankton. The habitat for microalgae lives in almost all waters in the world. Microalgae can carry out photosynthesis like other plants; therefore microalgae need sunlight and CO_2 gas to carry out the photosynthesis process. One type of microalgae is Spirulina Platensis (Bunowo & et al, 2018). Spirulina Platensis is a microalga that can grow well in low quality water such as wastewater in alkaline conditions with sufficient availability of nutrients and sunlight. Spirulina Platensis contains protein, amino acids, vitamins, minerals and pigments that can be used as additional food ingredients (supplements) for humans, animals, and aquaculture (Setiawan & et al, 2014).

One type of microalgae is Spirulina Platensis. Spirulina requires CO_2 gas to carry out photosynthesis; one kilogram of dry microalgae uses about 1.83 kg of CO_2 while the amount of use of CO_2/ biomass of Spirulina Platensis ranges from 0.36-1.78 g CO_2/ g biomass with an average of 0.78 g CO_2/ g of biomass at a rate of 750 ml/ min. (Setiawan & et al, 2014).

Growth of Spirulina Platensis is influenced by environmental conditions including temperature (temperature), nutrients (nutrients), light intensity, degree of acidity (pH), aeration (CO_2 source), and salinity. The following is the environmental quality standard for microalgae growth based on several literatures (Kawaroe, 2010). Spirulina is the type of microalgae that is most widely cultivated; this is due to its fast growth process, relatively low maintenance costs, and high nutrient content. The pigment content of Phycocyanin in spirulina is useful as an antioxidant, a natural colorant for food, cosmetics, and medicine, especially as a substitute for synthetic colors and can reduce obesity (Muhammad, 2010).

At PT. Indonesia Power UPJP Perak Grati microalgae spirulina platensis is used as an effort to reduce CO_2 gas emissions generated from the GSPP chimney. According to Yusuf Setiawan (Setiawan & et al, 2014), the amount of CO_2 that can be absorbed or used by Spirulina Platensis biomass is in the range of 0.36-1.78 g CO_2/ g biomass with an average CO_2 absorbed of 0.78 g CO_2/ g biomass. In addition, the dry biomass produced from the cultivation process is processed to become a fish feed mixture in collaboration with the community around the company as a Corporeate Social Responsibility (CSR) program.

In this study, we will discuss the use of Microalgae Spirulina Platensis to reduce CO_2 gas emissions generated from emissions from the power generation process of PT. Indonesia Power Unit for Generation and Generation of Grati Silver (UPJP PGT), especially in the Heat Recovery Steam Generator (HRSG) chimney. This research was conducted at the Microalgae Cultivation Unit which utilizes emissions from Heat Recovery Steam Generator (HRSG) number 1.1.

Methodology

Type and Conceptual of the Research

This study uses a quantitative approach. The research method used is an experimental method (Min, 2016). The scope of this research activity includes field activities. Field activities include experimental activities for microalgae cultivation by utilizing emissions from GSPP, especially in HRSG 1.1. This research is part of the activities carried out by the K3L Division of PT. Indonesia Power Unit for Generation and Service Generation (UPJP) Perak Grati. From this research, data will be obtained regarding light intensity, pH, and the amount of microalgae biomass obtained at harvest. Examination of pH and light parameters was carried out at the cultivation location using the available equipment.

The conceptual framework is a relationship between concepts or variables to be observed or measured through the research conducted (Soekidjo, 2005). The conceptual framework in this study can be described as seen in Fig. 1.

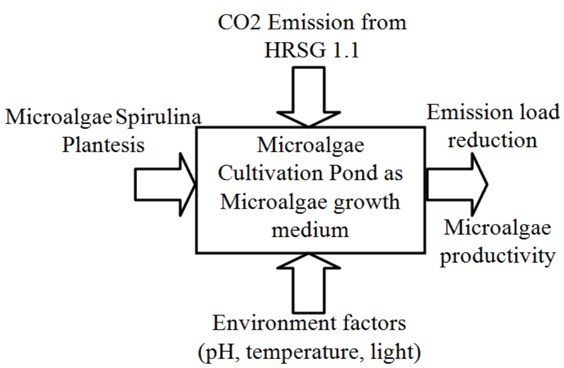

Figure 1. Research Concept Framework

Variables are measures or characteristics possessed by members of a group that are different from those of other groups (Soekidjo, 2005). The independent variable is a variable which if at any time changes will result in changes to other variables. The dependent variable is a variable that changes due to changes in the independent variable. The variables in this study are as seen in Fig.2.

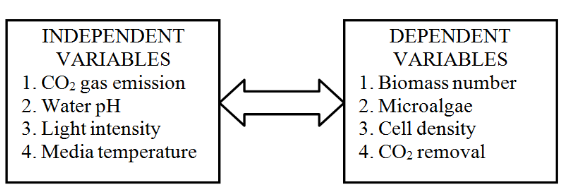

Figure 2. Variables in Research

Research Location and Sampling

The research was conducted at PT. Indonesia Power UPJP Perak Grati, which is located on Jl. Raya Surabaya Probolinggo KM 73. Wates Village, Lekok District. Regency. Pasuruan - East Java.

The population in this study was the Spirulina Platensis Microalgae that were cultivated in the Microalgae Installation of PT. Indonesia Power UPJP Perak Grati, by utilizing CO_2 gas emissions from HRSG 1.1.

The sample is part of the overall object under study and is considered to represent the entire population at the research site. The sampling technique used in this study was purposive sampling using inclusion criteria. The inclusion criteria were the characteristics of the sample that could be included or were eligible to be studied, while the inclusion criteria used were microalgae Spirulina Platensis. The microalgae are obtained from Indonesian waters and have been cultured by the Brackish Water Cultivation Fishery Center (BPAP) Situbondo, East Java. The microalgae seeds used have been reproduced in the company's environmental laboratory which will then be used as a starter for the cultivation process in the event of a failure in the cultivation process.

Data Sources

The primary data of this research are noise data. The primary data obtained in this study are data of light intensity, pH, pool temperature, the amount of biomass from microalgae yields. Data of lighting intensity, pH and pool temperature every day during the observation period by direct measurement. Secondary data in this study were obtained from existing data in the company and literature studies or related literature. Secondary data in this study include fuel consumption data in determining CO_2 emission load, microalgae installation design, etc. The Emission Load data used is data for the 1st Quarter (January-March) 2018, this is because the CO_2 emission load data for the 2nd and 3rd Quarter (April-September) periods are still in the process of being compiled by the company.

Study literature by conducting theoretical studies through books and other sources of information relating to the learning media that will be developed.

Research Design

This research includes 2 stages, namely: the Observational research stage and the Experimental research stage. The observational research stage includes secondary data analysis to determine the CO_2 emission load generated from HRSG 1.1. The data period to be analyzed is data in January-March 2018. While the experimental research stage is to cultivate microalgae spirulina platensis with the variations that have been determined during July 16 2018-July 29 2018. In the experimental stage the observations will be divided into 4 pools, namely Control Pool, Variation Pool 1, Variation Pool 2, and Variation Pool 3. Each pool will get different treatments. This treatment includes adjusting the flow rate of CO_2 that is flowed into the pool, there are 3 variations of the flow rate of CO_2, namely as follows:

1) Control Pool: Raw Water + Microalgae + Ordinary Aerator (Control)
2) Variation Pool 1: Raw Water + Microalgae + CO2 Aerator with V1 = 1 Liter/ minute.
3) Variation Pool 2: Raw Water + Microalgae + CO2 Aerator with V2 = 2 Liter/ minute.
4) Variation Pool 3: Raw Water + Microalgae + CO2 Aerator with V3 = 3 Liter/ minute

Data Analysis

In calculating the GSPP Emission Load, the calculation method in this study includes the calculation of CO_2 Emission Load and the calculation of CO_2 absorption by microalgae. The method for calculating the CO_2 load generated from HRSG 1.1 refers to the Minister of Environment Regulation No. 21 of 2008 concerning Fixed Emission Quality Standards for Thermal Power Plants Appendix VII (F) with the Equation (1).

$$E\ CO2 = \sum F \times Ac\ CC \times OF \times \left(\frac{MW\ CO_2}{AN\ C}\right) \quad (1)$$

Where OF is Oxidation Factor (0.95), MW CO2 is Molecular Weight CO_2 (44), AN C is Atomic Number C (12), E CO_2 is Emission Load CO_2 (ton), $\sum$F is Actual Carbon Content → 154 ton/ month.

Environmental factors are one of the factors that influence the growth of a living being. Environmental factors that will be observed in this study include:

1) light intensity,
2) pH of water
3) water temperature

Observation of environmental factors was carried out in all observation ponds (control pool, variation 1, variation 2 and variation 3). The data that has been collected will then be analyzed using the SPSS application to determine the correlation between environmental factors and microalgae growth using the correlation test method using the Pearson Correlation. Person correlation is a statistical method used to measure the strength and direction of the linear relationship of two variables. The correlation between these variables is connotated with a value of 1 to -1. The higher the correlation value is indicated by the closer the value to 1 or -1.

In this study, the influence of CO_2 gas will be calculated on the growth of the Spirulina Platensis Microalgae. The calculations are carried out still using the SPSS application using the one-way ANOVA (Analysis of Variance) test, because only one factor of concern is the growth of microalgae. In this experiment, several different treatments will be given to each microalgae sample.

The principle of the Anova test is to analyze the variability of data into two sources of variation, namely variations within groups and between groups. The results of this method are in the form of a comparison of the values of the two variants, where if the results get closer to the number one, there is no difference in the effect of the intervention carried out, in other words the mean value being compared is no difference and vice versa (Anisa, 2010).

The analysis of the amount of CO_2 that can be absorbed by this microalgae installation is calculated based on the amount of CO_2 emissions (tonnes) that are produced, reduced by the assumption that the amount of CO_2 gas that can be absorbed by microalgae. The amount of CO_2 that can be absorbed or used by biomass. The strength of the CO_2 absorption capacity of Spirulina Platensis is in the range of 0.36 - 1.78 g CO_2/ g of biomass with an average CO_2 absorbed of 0.78 g CO_2/ g of biomass (Setiawan & et al., 2014). The formula for calculating the absorption of CO_2 by microalgae is as Eq. (2).

$$absorbed\ CO_2\ (Ton) = \frac{harvest\,(kg) \times 0.78}{1000} \quad (2)$$

Result and Discussion

Production Activities of PT.Indonesia Power UPJP Perak Grati

The main business activities of PT. Indonesia Power is a provider of electricity through electricity generation and as a provider of operation and maintenance services for power plants that operate power plants spread across Indonesia.

The production process of GSPP Grati includes 3 blocks, namely, Block 1, Block 2 and Block 3. Block 1 (Combine Cycle) has been operated since October 1997 with a 3: 3: 1 system which itself 3 x 100 MW Gas Turbine, 3 HRSG (Heat Recovery Steam Generator) with 1 x 150 MW Steam Turbine. Block 2 (Open Cycle) which consists of 3 x 100 MW Gas Turbines. Since 2017 to date, an Add On or additional capacity is being carried out by installing 3 HRSG units and 1 Steam Turbine with a capacity of 1 x 150 MW. Since 2015, Block 3 (Combine Cycle) has been built consisting of 2 x 150 MW Gas Turbines and 1 x 150 MW Steam Turbines and is expected to be COD (Commmercial On Date) in November 2019.

Characteristic of Power Plant Emission

Monitoring exhaust emissions at GSPP Grati, using external laboratory analysis services and direct measurement using the Continous Emission Monitoring System (CEMS) tool. The data obtained from the last examination in March 2018 are as seen in Table 1.

Table 1. Emission Characteristics Data

No	Parameter	Unit	Standard***	Lab.	CEMS	Tolerance of Microalgae*
1	Particulate	mg/Nm3	30	1	2.2	200,000*
2	SO2	mg/Nm3	150	<1	0.06	400,000**
3	NO2	mg/Nm3	320	302	8.62	240,000*
4	Opacity	%	-	<20	-	-
5	Oxygen (O2)	%	-	15.8	15.8	-
6	Air flow	m/s	-	2.1	13.7	-

*) Brown (1996); **) Matsumoto (1997);
***) PermenLH no. 21 Tahun 2008

Research Result

Emission Load Calculation Results

Based on the calculation results, the CO_2 emission load of GSPP Grati in the January - March 2018 period is as displayed in Table 2.

Table 2. CO2 Emission Load of Grati Power Plant

	JAN	FEB	MAR
Emission Load CO_2	9.086	10.610	11.514

Based on the data above, the average emission load value generated from HRSG 1.1 is 10,403.31 ton CO_2/ month on average.

Environmental Factor Correlation Test Results Against Microalgae Growth

Changes in environmental factors that occur are observed and compared with changes in growth that occur. The following data were obtained during the 14 days of observation.

Lighting is an environmental factor that can affect the photosynthesis process of microalgae, and can affect the increase in surface temperature of microalgae cultivation pond water. The Figure 3 is the result of the average change in lighting intensity around the aquaculture pond.

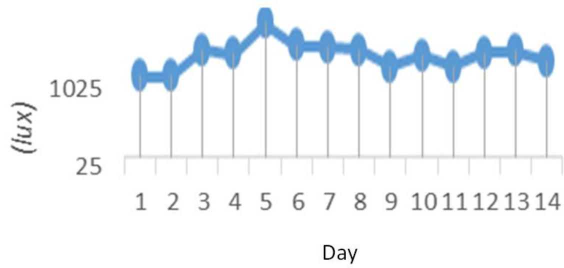

Figure 3. Graph of Light Intensity in Cultivation Pond

Lighting intensity measurements were carried out every day at 09.00, 12.00, 15.00 and 18.00. Based on the data above, the highest lighting intensity was on July 22, 2018, with an average value of 1,372 lux and the highest average lighting intensity was on July 20, 2019, which was 894 Lux.

Changes in water surface temperature are one of the factors that can affect the growth of microalgae spirulina platensis. The observed data for each variation are as seen in Fig. 4.

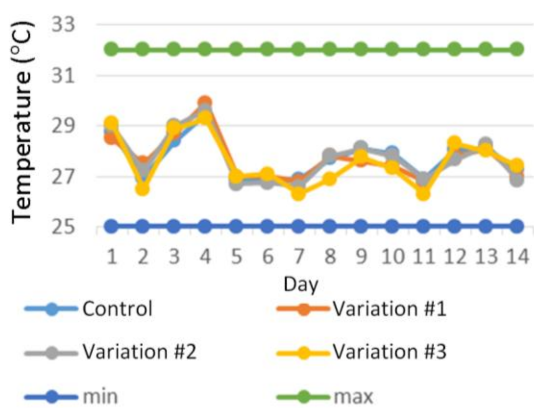

Figure 4. Graph of Changes in Surface Water Temperature in Cultivation Ponds.

The temperature changes that occurred in the cultivation pond were very fluctuating but tended to decrease, and the pond temperature in all treatments was still at the optimal temperature for microalgae growth, which was between 25-33°C.

Another environmental factor is the pH of water, where the ideal pH for microalgae growth is in the range of 5.5-9.5. The following is data from monitoring results and trending changes in the experimental pond pH during the observation period.

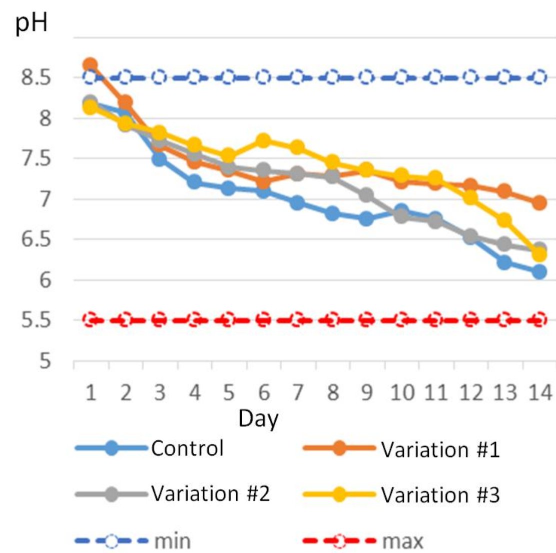

Figure 5. Graph of changes in the pH of the cultivation pond

The graph above shows a decrease in pH value in each pond even though the decrease is still within the optimal limit of microalgae growth. However, from the 4 observation pools, Variation Pool 1 showed a decrease that was not too significant so that on the 14th day the pH of the water was still at a value of 7.

Before conducting a correlation analysis, the data obtained will be tested using the Kolmogorov Smirnov test. The application of the Kolmogorov Smirnov test is that if the significance is below 0.05, it means that the data to be tested has a significant difference with standard normal data, meaning that the data is not normal. Furthermore, if the significance is above 0.05, it means that there is no significant difference between the data to be tested and the standard normal data. Based on the results of the Kolmogorov Smirnov distribution test data in this study, a significance value was obtained above 0.05, which indicates that the data was normally distributed. So that the correlation test can be done. Based on the results of the Pearson Correlation Test with the SPSS application, a summary of the correlation values is obtained as seen Table 3.

Table 3. Correlation Test Results between environmental factors and microalgae growth

	Statistic test	Light intensity	Temperature	pH
Microalgae Growth	Korelasi	0.009	**-0.329**	-0.487
	Signifikansi	0.946	**0.013**	0.000

Analysis of the Effect of CO2 on Microalgae Growth

Microalgae cultivation ponds that are given a regulation of the amount of CO2 flow will then be observed for cell growth by weighing the dry weight every day from the beginning of cultivation to the harvest period. Based on the results of observations, data were obtained as seen in the Fig. 6.

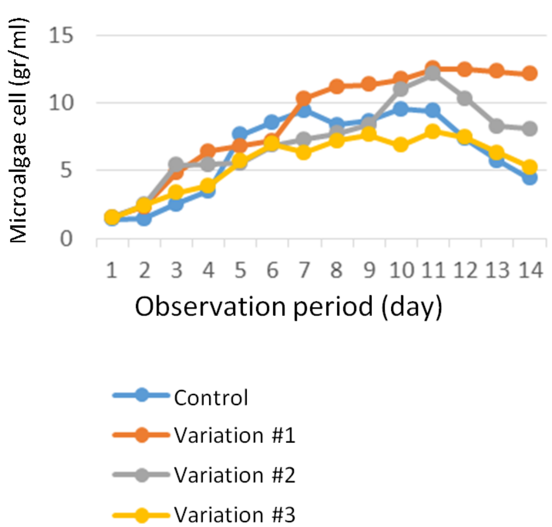

Figure 6. Graph of Microalgae Growth in each cultivation pond

Based on the data, it can be seen that the growth of microalgae with variation 1 or with a CO2 flow rate setting of 1 liter/ minute shows a more stable growth, when compared to other variations.

Furthermore, based on the data that has been obtained, an ANOVA test will be carried out to determine the effect of adding CO2 gas to the growth of microalgae. Before the ANOVA test is carried out, the variance homogeneity test and normalized test will first be carried out to ensure that the data obtained is homogeneous and normally distributed.

Based on the results of calculations using the SPSS application, the ANOVA test results were obtained as follows:

Table 4. ANOVA Test Results on Microalgae Growth

ANOVA					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	113.243	3	37.748	5.262	**.003**
Within Groups	372.996	52	7.173		
Total	486.238	55			

Based on the data above, it shows a significance value of 0.003 or less than the probability value (p-value) <0.05, this indicates that Ho is rejected. As well as the value of F = 5.262 if we compare it with the data in Table F (See Appendix) the F value in the table with Df1 = 3 and Df2 = 51 obtained an F value of 2.78 so that from the results above it is known that F count> F table, so Ho was rejected and a further test would be carried out (Post Hoc Test). So that the provisional result of this test is that the addition of CO_2 affects the growth of microalgae. So to find out which treatment has the most effect, a Benferoni Post Hoc Test is carried out. Table 4.5 below is the data from the follow-up test results.

Table 5. Post Hoc Test Results (Benferoni)

Multiple Comparisons

Dependent Variable: Microalgae Growth

Bonferroni

(I) Flow rate	(J) Flow rate	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Control	CO_2 1 L / min	-3.08071*	1.01228	.022	-5.8574	-.3041
	CO_2 2 L / min	-1.17214	1.01228	1.000	-3.9488	1.6045
	CO_2 3 L / min	.66500	1.01228	1.000	-2.1116	3.4416
CO_2 1 L / min	Control	3.08071*	1.01228	.022	.3041	5.8574
	CO_2 2 L / min	1.90857	1.01228	.390	-.8681	4.6852
	CO_2 3 L / min	3.74571*	1.01228	.003	.9691	6.5224
CO_2 2 L / min	Kontrol	1.17214	1.01228	1.000	-1.6045	3.9488
	CO_2 1 L / min	-1.90857	1.01228	.390	-4.6852	.8681
	CO_2 3 L / min	1.83714	1.01228	.452	-.9395	4.6138
CO_2 3 L / min	Kontrol	-.66500	1.01228	1.000	-3.4416	2.1116
	CO_2 1 L / min	-3.74571*	1.01228	.003	-6.5224	-.9691
	CO_2 2 L / min	-1.83714	1.01228	.452	-4.6138	.9395

*. The mean difference is significant at the 0.05 level.

Based on the data above, the treatment results that have a significant impact on the growth of microalgae are the addition of CO_2 of 1 liter/ minute.

Calculation of CO_2 absorption by microalgae

The following is a comparison of the yields of microalgae in each experimental pond shown in Table 4.6.

Table 6. Experimental Pond Harvest Data

No	Pond	Harvest (kg)
1	Control	8.37
2	V1 (1 L.CO_2 /Min)	23.05
3	V2 (2 L.CO_2 /min)	15.36
4	V3 (3 L.CO_2 /min)	9.97

The yield of the V1 pool with the addition of 1 liter of CO_2/ minute yielded greater microalgae bioass than other ponds, then the V1 yield data will be calculated to determine the amount of CO_2 that can be absorbed by the microalgae.

Harvest result V1 = 23.05 Kg

Microalgae CO2 absorption = 0.78

Based on the calculation results, the amount of CO_2 that can be absorbed by the microalgae biomass in the V1 cultivation pond is 17.2875 Kg. If it is assumed that each cultivation cycle produces the same biomass as in pond V1, here is the amount of CO_2 that can be absorbed by the GSPP Grati microalgae installation for 1 month (2 cultivation cycles):

CO_2 Emission Load Average HRSG 1.1: 10,403.31 Ton CO_2/ Month

CO_2 Absorption/ Pool: 0.00173 Ton CO_2/ Cycle

Number of Microalgae Ponds: 8 Ponds.

Microalgae Installation CO_2 Absorption:

$= 8 \times 0.00173$

$= 0.1383$ Ton CO_2 /cycle

$= 2 \times 0.1383 =$ 0.2766 Ton CO_2/ month

Based on the results of these calculations, the amount of CO_2 that can be absorbed by the GSPP Grati microalgae installation every month is 0.2766 tons of CO_2/ month or <1% CO_2 emission load/ month.

Conclusion

Based on the results of the research that has been done, several conclusions can be drawn and at the same time answer the objectives of this study. The following are some of the conclusions that can be drawn from this study:

1. Based on the calculation results of CO_2 Emission Load refers to the Regulation of the Minister of Environment No. 21 of 2008 concerning Stationary Emission Quality Standards for Thermal Power Plants Appendix VII (F), the total monthly average CO_2 emission load produced is 10,403.31 tonnes.
2. Based on the research results, the growth of microalgae cells has a correlation with 2 of the 3 environmental factors observed. There is a correlation between the growth of microalgae cells with light intensity, where

changes in light intensity are directly proportional to the growth of microalgae cells. In addition, there is also a correlation between changes in pH and the growth of microalgae cells, where the growth of microalgae cells is inversely proportional to changes in the pH of culture water.

3. Based on the analysis, it is concluded that the addition of CO_2 gas emissions from HRSG 1.1 affects the growth of microalgae cells. Of the 4 (four) variations in the flow rate of CO_2 emissions given, the pond with a flow rate of 1 Liter CO_2/ minute showed a significant change in growth.
4. The amount of CO_2 absorption by microalgae installations with a flow rate variation of 1 liter CO_2/ minute can absorb 0.2766 tons of CO_2/ month, or only <1% per month of the average emission load of HRSG 1.1. So it is necessary to do further studies to increase the productivity of the microalgae spirulina platensis in order to reduce the burden of greater CO_2 emissions.

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