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Methane and Carbon Dioxide Emissions in the Palm Oil Wastewater Treatment Process at PTPN XIV East Luwu Regency

Fitriana Syarifuddin[1], Erniwati Ibrahim[2], Alimin Maidin[3], Anwar Mallongi[2], Amran Razak[4]

[1]Student Master Program in Public Health Postgraduate School of Hasanuddin University, Makassar, South Sulawesi, Indonesia
[2]Department of Environmental Health Faculty of Public Health Hasanuddin University, Makassar, South Sulawesi, Indonesia
[3]Department of Hospital Administration, Faculty of Public Health Hasanuddin University, Makassar, South Sulawesi, Indonesia
[4]Department of Health Policy Administration, Faculty of Public Health Hasanuddin University, Makassar, South Sulawesi, Indonesia

Corresponding Author: Fitriana Syarifuddin

ABSTRACT

Processing waste with an open pond is indeed able to reduce the levels of organic matter in liquid waste through the fermentation process of these organic materials by the bacteria forming methane. However, the by product of the fermentation process produces methane and carbon dioxide which can increase the concentration of Greenhouse Gases (GHG), which causes global warming. This study aims to determine the success of palm oil wastewater treatment process based on Methane (CH4) and Carbon dioxide (CO2) emissions at PT. Perkebunan Nusantara XIV, East Luwu Regency.
Data analysis techniques using laboratory tests which then calculate emissions using a formula adopted from the International Atomic Energy Agency (IAEA) to determine the value of gas emissions emitted from ponds of WWTP PT. Perkebunan Nusantara also analyzes sources of organic matter on wastewater with using laboratories.
The results showed that the concentration of methane gas and carbon dioxide produced from each WWTP pool varied, this was due to the decrease in the number of different COD values in each WWTP pond which was also influenced by the pool characteristic and the amount of mud in the pond. The highest value of methane gas emissions occurred during the daytime at pool 2 (anaerob) of 4314.74 x 10^3 mg $m^{-2}min^{-1}$ and pond 6 (sedimentation) of 1235.93 x 10^3 mg $m^{-2}min^{-1}$ and the emission value needed occurred in pond 4 (Aerob) in the afternoon at 24.23 x 10^3 mg $m^{-2}min^{-1}$ and the highest value of carbon dioxide emissions in pond 1 (Anaerob) during the day is 7111.83 x 10^3 mg $m^{-2}min^{-1}$ and the smallest emission value in pool 4 during the day is 280.09 x 10^3 mg $m^{-2}min^{-1}$. Total penurunan nilai *COD* pada kolam anaerob sekitar 79.19 % dan kolam sedimentasi adalah 58 %. Dimana, setiap penurunan 1 mg *COD* akan menghasilkan 0,45 kg/m^{-2} gas metana.

Keywords: Emissions, Methane (CH_4), Carbon dioxide (CO_2), POME, WWTP, Greenhouse Gases, Global Warming.

INTRODUCTION

The plantation sector is one of the sectors that handling a strategic role in development with the value of world coconut oil production of 69.8 million tons in 2017 and the two countries which are the largest palm oil producers in Malaysia and Indonesia. The high value of world palm oil production is due to an increase in world oil demand with a total world demand for palm oil in 2015 of around 64.5 million tons and is expected to increase to 95.7 million tons in 2025. [1,2]

CPO production in Indonesia in 2017 has reached 41.98 million tons. This figure shows an increase in production by 18% compared to production in 2016, which was 35.57 million tons. [3] In South Sulawesi Province, palm oil production in 2015 was 72,691 tons and East Luwu

Regency was 2259 tons. [4] Palm Oil Processing Plant (PPKS) is a place for processing oil palm Fresh Fruit Bunches (FFB) into palm oil products such as CPO (Crude Palm Oil) and PKO (Palm Kernel Oil). [5]

In the production of Crude Palm Oil (CPO) 35 million tons per year has the potential to produce Palm Oil Mill (POME) waste of 135 million m3 POME per year. [6] The newly produced Liquid Palm Oil Waste (LCPKS) generally has an acidic temperature of 60°C – 80°C (pH 3.4-4.6) and has a very high content of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). [7] The high content of organic matter in palm oil liquid waste, requires palm oil mills to do processing first, so that wastewater is wasted can be tolerated by the environment. [8]

In general, the processing of Oil Palm Mill Liquid Waste (LCPKS) is carried out using a series of open ponds consisting of anaerobic, facultative and aerobic ponds followed by land application to reduce the environmental burden for the sustainability of the oil palm industry. [9] However, the limitation of this system is that it requires more extensive, time consuming land and releases methane gas directly into the atmosphere from decomposition of organic matter by anaerobic microorganisms that occur in anaerobic ponds. [10]

Anaerobic processing will decompose organic compounds in wastewater by hydrolysis and fermentation which involve various anaerobic bacteria (metabolic bacteria that survive only on anaerobic conditions) which are further reduced to Carbon Dioxide (CO_2), Methane (CH_4), Ammonia and Hydrogen Sulfate (H_2S). [11]

Methane gas (CH_4) produced in each pond WWTP anaerobically, has two different sides, namely as a renewable energy source and as one of the compounds of Greenhouse Gases (GHG). The potential of CH_4 gas is 21 times greater than the potential of CO_2 gas, so CH_4 gas greatly contributes to the increase in the surface temperature of the earth. [12] The release of methane gas in the atmosphere for a period of about 7-10 can increase the temperature to around 1.3°C per year. [13] Whereas for CO_2 levels it has an influence on combustion of methane gas. [14]

PTPN XIV East Luwu Regency is one of the palm oil processing plants in South Sulawesi Province using an open pond system in processing palm oil waste using methanobacterium omelianskii bacteria producing methane in wastewater. Therefore, the study aims to determine the success of palm oil wastewater treatment processes based on Methane (CH_4) and Carbon Dioxide (CO_2) emissions at PTPN XIV, East Luwu Regency.

MATERIALS AND METHODS

Location and Study Design

This research was conducted in November 2018 - February 2019. The research process was carried out at the WTP (PTTP XIV) Water Treatment Plant in East Luwu Regency. This study uses a quantitative design with a descriptive analytical approach that aims to provide an overview of the variables studied on samples of methane (CH_4) and Carbon Dioxide (CO_2) emissions taken from each pond of WWTP PTPN XIV, East Luwu Regency.

Sample Research

The sample in this study was 72 samples of methane gas and 72 samples of carbon dioxide and 12 samples of wastewater from each pool.

Method of Collecting Data

The process of taking gas and waste water is carried out for 2 days. On the first day, installing a containment tube in each pool of WWTP which serves to capture the gas produced from each pond WWTP and containment tubes left floating for 1 x 24 hours above the surface of the pond. Then gas and wastewater sampling is carried out in each pond of WWTP. Samples of Methane and Carbon Dioxide gas were taken simultaneously using a 10 ml syringe which was injected into the septal rubber where the sample gas was taken in the containment tube then injected into a 10 ml vial bottle and saw the temperature value on the thermometer installed in the containment tube. The gas sampling was carried out at different times (morning, afternoon and evening) with intervals of 5,10,15 and 20 minutes respectively.

Furthermore, wastewater sampling was carried out, which was carried out on the same day in each IPAL pool using a 600 ml bottle which aims to examine BOD, COD, TSS and pH. The parameters of the pool fluid temperature are taken during waste water sampling. Then the gas samples that have been taken are sent to the Pati - Semarang Greenhouse Gas Laboratory by using 144 ml vial bottles of 144 samples and placed in a cork box which will then be analyzed for 14 working days and for the wastewater samples taken, taken immediately to the Makassar Health Laboratory Center using a cork box and then analyze it for 14 working days.

Data Analysis

Analysis of gas and waste water sample data was carried out using laboratory tests to determine the value of gas emissions and organic wastewater which then calculated the amount of methane gas emissions using a formula adopted from the International Atomic Agency (IAEA) in 1993.

RESULTS

Live Time Analysis

The residence time of liquid waste in each pond WWTP PTPN XIV can be seen in table 1.

Table 1 : POME Stay Time Based on the Depth of PTPN XIV WWTP Pond in Burau District in 2019

No	Pond	Live Time
1	Pond 1 (Anaerob)	10
2	Pond 2 (Anaerob)	10
3	Pond 3 (Facultative)	10
4	Pond 4 (Aerob)	4
5	Pond 5 (Aerob)	8
6	Pond 6 (Sedimentation)	13

Table 1 displays the different residence times, the longest residence time in pool 6 and the shortest residence time in the pond 4. The residence time of waste depends on the hydrolysis reaction of palm oil mill effluent which is combined with the return of COD decomposition, the longer the waste remains the more organic particles decompose. [15]

Degradable Organic Component

The main factor in determining the potential for the formation of methane gas (CH4) in wastewater is the amount of organic matter degraded from wastewater. The parameters most often used to measure degradable organic component (DC) from waste water are BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand). [16]

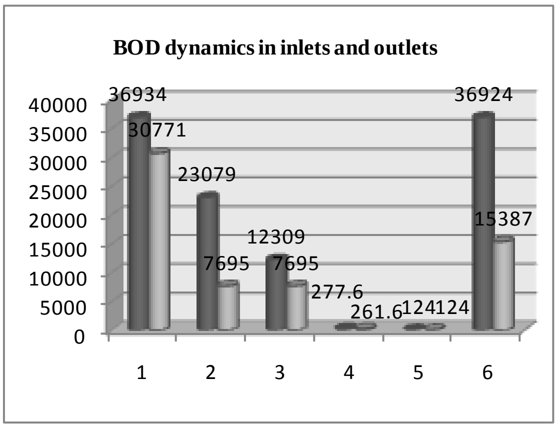

Figure 1: BOD dynamics in inlets & outlets IPAL PTPN XIV

Figure 1 is an illustration of the BOD value in the inlet and outlet in each pond of WWTP. The BOD value states the amount of organic matter in liquid waste. The more amount of organic matter that can be oxidized in liquid waste, the higher the value of BOD. [17] In figure 1, it is illustrated that in pool 2 and pond 6 the highest BOD value decreases. In pond 2 there is a decrease in BOD value of 15,384 mg / l or 66% and similarly in pool 6 the decrease in BOD value is 21,537 mg / l or 58%. This decrease in the BOD value in pond 2 and pond 6 indicates that there are at least organic substances that are oxidized by microorganisms.

In pond 4 and pond 5 the BOD value is reduced due to the lack of organic substances oxidized by microorganisms. at the aeration stage there is decomposition of organic substances by microorganisms. To decompose organic substances, microorganisms need oxygen to be able to break it down easily in liquid waste. [17]

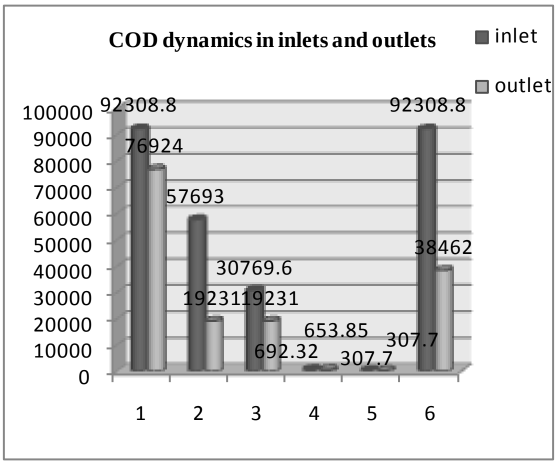

Figure 2: COD dynamics in inlets & outlets IPAL PTPN XIV

Chemical Oxygen Demand (COD) is a recommended parameter for estimating the degradation of organic materials in wastewater. [16] Figure 2 illustrates the changes in the COD value in the inlet and outlet in each pond of WWTP. The highest decrease in COD value is found in pond 2 and pond 6. In pool 2 the decrease in COD value is 38,462 mg / l or 67% and in pond 6 is 58%. The decrease in COD value is due to the lack of oxygen supply in pond 2 and pond 6 and is influenced by the residence time of waste because bacteria need time to decompose organic compounds into biogas. [15]

Apart from the BOD and COD values, the degradation process of organic matter in liquid waste is also caused by other waste parameters such as TSS, pH and temperature which also contribute to the formation of gases in liquid waste.

Total Suspended Solid (TSS) or total suspended solids are suspended solids in water in the form of organic and inorganic materials. TSS can affect turbidity and can interfere with activities in the water environment. Figure 3 illustrates the TSS values in the inlets and outlets of each WWTP pond. Described a decrease in TSS value from pool 1 to pool 6 between before and after processing ranged from 24% to 99% with an average TSS reduction obtained at 44.5%.

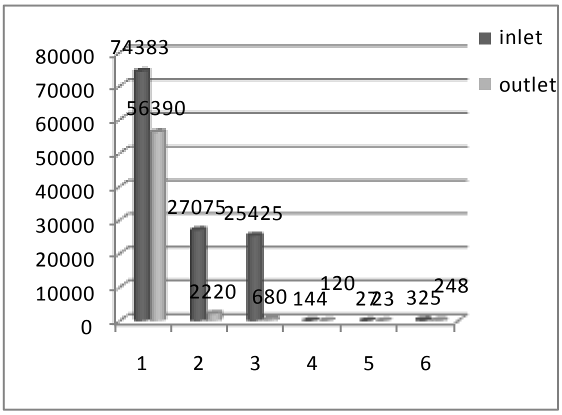

Figure 3: Results of Parameter Analysis of TSS (Total Suspended Solid) in pond Inlet and outlets WWTP of PTPN XIV Burau

The value of Total Suspended Solid (TSS) continues to decline due to the deposition process at the bottom of the pond so that when the sampling of sludge in the pond is not included with liquid waste and the volume of liquid waste that comes out in the outlet is still in small volume so physically the liquid looks not solid. Suspended solids can be reduced through a good deposition process in the liquid waste treatment process. [18]

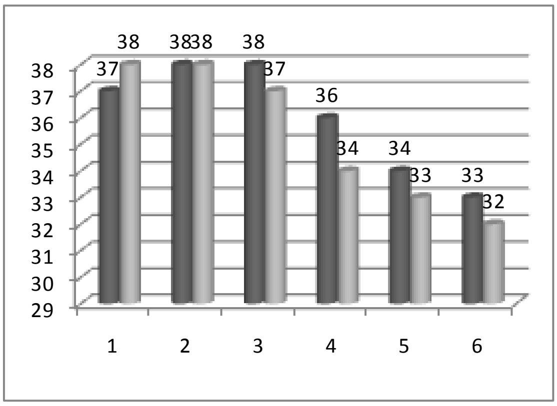

Figure 4: Results of Analysis of Temperature Parameters in Inlet and outlets WWTP of PTPN XIV Burau in 2019

Figure 4 shows the temperature of the highest pool liquid in pond 1 to pond 3 which is an anaerobic pond and facultative pond with a pool liquid temperature of around 35-40oC. Pool 1 and pond 2 are anaerobic ponds which are the first and second pools as a place for decomposition (degradation) of organic materials by the methanobacterium omelianskii bacteria which are the bacteria forming methane gas.

Pond 3 is a facultative pond which is a transition pool from anaerobic pond to an aerobic pond which is also called the deactivation process of anaerobic bacteria and the pre condition of the aerobic process of this activity can be identified by the scum (foam bubbles) and liquid appearing greenish.

In pond 3, the temperature ranges from 37-38°C. This pond is still in the process of degradation of organic matter, causing fluid temperatures to increase due to the activity of microorganisms in wastewater. Whereas ponds that have the lowest temperatures in ponds 5 and 6 due to the pool edge, there are planting shady trees such as trembesi trees and banyan trees that protect the pond from direct sunlight.

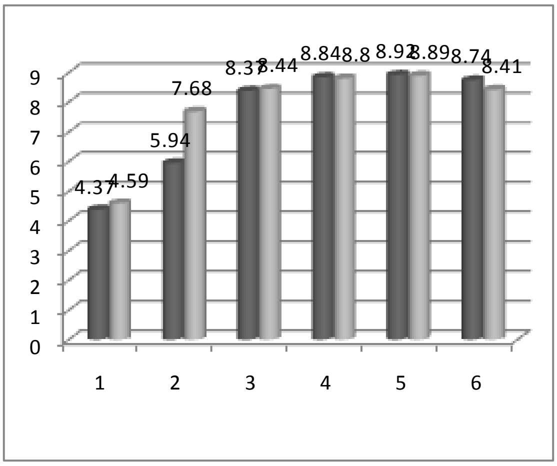

Figure 5: Results of Analysis of pH Parameters in Inlet and outlet WWTP PTPN XIV Burau in 2019 year

This pH affects biological life in water and the environment around water. The pH of alkaline palm wastewater which ranges from 7.45-9.65 is a suitable place for the growth of microorganisms in the process of decreasing BOD and COD of palm oil liquid waste. [19] Figure 5 shows that ponds 1 and 2 have low pH values ranging from 4,48-6,81 which are still acidic. However, palm oil liquid waste at pH 6 has been able to produce methane. [20] Whereas in pond 3 to pond 6 the pH values ranged from 8,40 - 8,58 were alkaline. Methane gas is best produced under conditions of pH 8.5. [21] In pond 4 and pond 5 the pH value increases due to the aeration stage. At the stage of aeration organic matter is slightly decomposed by microorganisms. The fewer organic substances that are broken down by microorganisms, the pH become more alkaline and if more organic matter breaks down the more acidic pH produced. [18]

Methane Emissions (CH_4)

The value of methane gas emissions in each pond of WWTP PTPN XIV can be seen in table 2

Table 2: Methane Emissions in each pond of WWTP PTPN XIV

No	Pond	The Value of Methane Emissions x103 (mg m-2 min-1)		
		Morning	Noon	Afternoon
1	Pond 1	710,15	1046,46	1056,73
2	Pond 2	1315,36	1660,57	1184,24
3	Pond 3	197,84	291,25	146,83
4	Pond 4	43,98	48,81	39,33
5	Pond 5	57,24	65,80	53,19
6	Pond 6	1340,99	1364,1	1260,61

Table 2 shows the value of methane gas emissions in each pond WWTP, with the highest methane gas emissions occurring during the daytime in pond 2 of 1660.57 x 10^3 mg $m^2 min^{-1}$ and pond 6 with a value of 1364,1 x 10^3 mg $m^2 min^{-1}$ which means every one minutes during the day with a surface area of 1 square meter capable of issuing emissions and the smallest emission value occurs in pond 4 in the afternoon with an emission value of 39,33 x 10^3 mg $m^2 min^{-1}$.

Carbon Dioxide Emissions (CO_2)

Then table 3 shows the amount of carbon oxide emissions produced from each WWTP pool, the highest carbon dioxide emissions in pond 1 during the day amounting to 20986,13 x 10^3 mg m^{-2}minutes^{-1} which means every one minute during the day with a surface area of 1 square meter pond 1 and the lowest emission value in pond 4 during the day with an emission value of 862,91 x 10^3 mg m^{-2}minutes^{-1}.

Table 3: The Emissions of Methane in each pond WWTP of PTPN XIV

No	Pond	The Emissions Value of Carbon Dioxide x 103 (mg m-2min-1)		
		Morning	Noon	Afternoon
1	Pond 1	7142,82	20986,13	14566,73
2	Pond 2	12609,51	8725,066	5364,89
3	Pond 3	4009,59	3351,27	2427,10
4	Pond 4	890,89	862,91	1409,91
5	Pond 5	1232,73	1487,60	972,94
6	Kolam 6	5303,97	3735,42	1423,45

DISCUSSION

Processing of waste with an open pond is indeed able to reduce the levels of organic matter in liquid waste through the fermentation process of these organic materials by the bacteria forming methane. But the byproducts of the fermentation process produce methane and carbon dioxide which can increase the concentration of Greenhouse Gases (GHG), causing global warming Value of Carbon Dioxide Emissions.

In this study gas sampling and liquid waste was carried out at WWTP. Gas extraction is carried out on two types of gases which are Greenhouse Gases (GHGs), namely Methane and Carbon Dioxide. 72 samples of Methane gas and 72 Carbon Dioxide gas samples were taken at different times, namely morning (07.00 WITA), noon (12.00 WITA) and afternoon (16.00 WITA) at intervals of 5,10,15 and 20 minutes respectively. . Then the liquid waste samples were taken at the inlet and outlet of each WWTP pool as many as 12 samples.

The highest value of methane gas emission in pond 2 was 1660,57 x 10^3 mg m^2menit^{-1} and pond 6 was 1364,1 x 10^3 mg m^2menit^{-1} which occurred during the day while the highest value of carbon dioxide gas emissions in pond 1 during the day was amounting to 20986,13 x 10^3 mg m^2menit^{-1}. The high methane gas emissions in pond 2 and pond 6 are influenced by the pool characteristics of WWTP based on a decrease in the high BOD and COD values in both ponds. Correlation relationship between methane gas emissions and COD where each one kilogram of COD is released will produce 0.109 kg (109 mg) of Methane. [22] When referring to the value of COD loss, in this study the decreasing value of each pool is multiplied by the pool volume and multiplied by the discharge of wastewater which is then divided by the emissions produced by each pool obtained every decrease of 1 mg COD will produce 0.45 kg / m methane gas.

The level of gas emissions released into the atmosphere depends in part on the physical structure of pond that affects light, temperature, oxygen content, and microbial assemblages. [23] In addition, accumulative methane gas formation is determined by the presence of basic ingredients, populations and microbial activity producing methane. [24]

While the highest value of carbon dioxide gas emissions in pond 1 is 20986,13 x 10^3 mg m^2min^{-1} (20,986 kg m^{-2} minutes^{-1}). Carbon dioxide emission value is higher compared to methane gas emissions in each IPAL pool because the fermentation process in the formation of acids and methane gas from a simple organic compound in an anaerobic reaction involves many branching reactions that produce carbon dioxide, so that in each process of forming methane gas will also produce carbon dioxide gas. [25] The emission of methane gas, temperature, organic matter and pH affects respiration and carbon dioxide concentration. [26]

In the previous study, obtained the value of gas emissions based on a decrease in the value of BOD and COD. The highest value of methane gas emissions was in anaerobic ponds but in the afternoon. With the highest value of methane gas emissions of 358.64 x 10^3 mg m^2min^{-1} and the highest carbon dioxide value of 402.145 x 10^3 mg m^2min^{-1}. [27] The next study explained that the decrease in the value of BOD and COD every time interval was due to organic material in liquid waste as nutrients for microorganisms and produced by biogas and during the anaerobic process the pH value of liquid waste took place around 6 and at pH 6 was able to produce methane.

[20] In addition, the next study says that methane flux is influenced by the size of the pool, which is a size of 5 m wide, yields 542.20 methane gas, 258.57 kg CO2-e^{-1}. [28]

CONCLUSION

The highest value of methane gas emissions is found in pool 2 and 6 during the daytime which are influenced by the characteristics of ponds and organic materials in liquid waste. Meanwhile, the highest value of carbon dioxide gas emissions is in pond 1 during the daytime.

Recommendation

For further researchers, they can conduct research by estimating that greenhouse gases can be produced by each pool of WWTPs, measuring ambient air around the WWTP pool to see the concentration of methane gas released into the atmosphere around the WWTP pond, and seeing the value of fluctuating methane and carbon emissions dioxide produced from the WWTP pond in a year needs to be repeated every month.

Conflict of Interest

The author agrees that there is no conflict of interest

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