Analysis and Managementof Methane Emissions from Dumping Pond: A Cases Study at FeldaJengka 8 Palm Oil Mill

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ABSTRACT

Palm oil production is major agricultural industry in Malaysia, in which palm oil mill effluent (POME) are considered as major waste. These waste products create a huge amount of treated POME sludge into dumping ponds. This paper will focus on theoretical methane emission from the treated POME sludge and establish the effective management practices. The treated POME sludge was collected from dumping ponds in FeldaJengka 8 palm oil mill. The results showed that the sludge content yield of biogas is 0.18 m^3 / kgVS, while methane yield production was 0.15 m^3 / kgVS. Total methane emission per dumping pond was 2.92 m^3 /ha. Indeed, it showed potential contribute for greenhouse gasses emission. Meanwhile, financial viabilities of biogas production and biofertilizer projects was obtained in palm oil mill with and without clean development mechanism (CDM). Biogas is captured from closed digestion tank treating POME sludge and converted to green renewable electricity, while biofertilizer were compared viabilities.The financial analysis for 12 years project term analysis indicated that CDM gave a significant effect and ensured economic viability for both project with 15% of internal rate return (IRR), RM 0.9 million of net present value (NPV) and 5 year of payback period (PBP). It is concluded that biogas production and biofertilizer provide additional opportunities for palm oil mills to utilize biomass by products actively with additional financial support of CDM. It is advantageous for the palm oil mills to obtain additional profits through utilizing excess biomass. Furthermore, this technology adaption can improve the surrounding environment by utilized treated POME disposal in optimum used.

Keywords:*Biogas emission, dumping ponds, treated palm oil mill effluent sludge, financial analysis*

Introduction

In Malaysia was planted with 4.69 million hectares of land with oil palm fresh fruit bunches (OPFFB) each year. According to Tan et al., (2010), Malaysia is the second largest palm oil producer, with 406 active palm oil and a total annual processing capacity of 92.78% million tones. In addition, the waste generated by the industries is a major environment concern and adverse effect. The component in OPFFB can be spared into palm kernel, mesocarp fiber, palm kernel shell, OPEFB and sludge (Wan Razaliet al., 2012). However, it this study was focusing on the substrate of treated POME sludge that collected in the dumping pond in the FeldaJengka 8 Palm Oil Mills, Bandar Tun Abdul RazakJengka, Pahang. By using the formula Bush and Naeve (1930) in searching the answer of the equation on anaerobic digestion for production of biogas and methane yield was obtained. This formula already proven significantly useful by Rodriguez et al., (2011), Nandet al., (1990), Labatutet al., (2011) and (Davidssonet al., 2007) for other wastes.

The POME sludge which can produce highly nutritive value can be identified by laboratory test that investigates the content of the sludge. This includes nutrient value, heavy metal, pH value, morphology characteristic and moisture percentage. This data is important to identify the key feature to identify the demand of methane emission on theoretical basis for POME sludge. In addition, recommended Clean Development Mechanism (CDM) projects for utilizing the POME sludge. Potentially, set-up the closed digestion tank which was mainly converted the POME sludge into renewable energy. Indeed. It was based on the financial analysis using the net present value (NPV) and internal rate return (IRR) as the financial indicator.

Materials and Methods

Field Methods

Twenty samplesof POME sludge were obtainedfrom dumping pond at FeldaJengka 8 Palm Oil Mill. Samples collected in four different sub-plot (1, 2, 3 and 4) within four week.Sampleswere storage in -20°C (Wan Razali*et al.*, 2012) with transparent seal bag.

Laboratory methods

Samples were dried in an ovenat 105°Cuntilaconstantweightwasachieved (24 hour). Thus, the dry sample was grinded in 2μm sizes. Thebasicanalysesincluded CHNS/O, heavy metal, pH, morphology, solid analyses (total solid, suspended solid and volatile solid) and moisture. Value of element was performed using CHNS/ analyser a2400SeriesIICHNS/Oelementalanalyser(PerkinElmer,USA) and heavy metal was performed using ICP-OES (Perkin Elmer - Optima 5300 DV). pH value was determined using (Mettler Toledo S20-K) and sludge morphology structure performed using field emission scanning electron (Carl Zeiss Supratm 40VP). Solid analysis wasperformedusingthe wastewater methoddescribedby APHA (1998). Lastly, was collected data of moisture content for sludge's.

Theoretical biogas and methane yield

Calculation biogas and methane yield was the characterization of the POME sludge to obtain their composition. Utilization theoretical biogas production and the amount of methane fraction may be foreseen on the field of the organic matter elemental composition. Buswell and Neave (1930) suggested an equation derived from stoichiometries balance of the quantity of organic matter (formula $C_aH_bO_cN_d$) to be biodegraded and the gaseous from anaerobic biodegradation. The general balance and in particular as the maximum theoretical biogas and methane specific production was applied;

$$*B_{th}\left[\frac{m^3}{kgvs}\right] = \frac{a*22.415}{12a+b\ 16c+14d}$$

$$*M_{th}\left[\frac{m^3}{kgvs}\right] = \frac{\frac{4a+b-2c-3d}{8}*22.415}{12a+b\ 16c+14d}$$

**B_{th} = Biogas production, *M_{th} = methane production*

Economic baseline value

In this study, the data for the palm oil mill operation were obtained from FeldaJengka 8 palm oil mills. The description of the operation is summarized Table 1. The processing capacity of the mill is 50t/hr FFB and approximately 288,000 t FFB can be process in a year. Palm oil processing facility require about 13-14 kWh/t FFB, which is provided 650 kW. Located a series of open POME treatment with capacity 3,125m^2. All prices used in the palm oil mill were based on the current value in Malaysia. Thus, electricity price generated by renewable energy through a national grid is 0.32 per kWh. CER price is based on the international carbon trade market at 42/t CO_2 in 2012. Indeed, diesel price is RM1.85/l which is the retail price at the mill. The facilities set-up and investment costs were referred to the actual project in FeldaSertingHilir and Sri Senggora palm oil mill for biogas power plant CDM project, and the estimation for biofertilizer project was based on the information given by Felda Palm Industries Sdn. Bhd.

Parameter	Description
Location	FeldaJengka 8 palm oil mill, Bandar Tun Abdul RazakJengka, Pahang.
Processing capacity FFB	50 t/h
Annual capacity	40 t/h x 24 hour x 25 day x 12 month (288,000 t FFB)
Water demand	5-6 t/t CPO
Steam demand	300 kg/t FFB
Electricity demand	13-14 kWh/t FFB
Capacity of steam turbine	650 kW x 2
POME treatment method before CDM project	A series of open anaerobic open tanks and lagoons
Each open anaerobic tanks capacity	(25m x 25m x 5m =3,125m^2)

In this study, two different projects as biogas production and biofertilizer were explored separately. Both projects were financially evaluated and compared using general indicators criteria with NPV, IRR, PBP and sensitivity analysis.

Results

POME sludge element has been observed in the laboratory. It shows difference element including the CHNS/O and heavy metal. In this, Table 2 the results of the physical-chemical charaterization of POME sludge samples. C/N ratio, volatile solids (VS), pH value and moisture content are the most important parameters to consider in planning an anaerobic digestion process. Common value of these parameter reported for a correct anaerobic digestion are C/N ration between 25 and 30, pH value between 6.5 and 7.5 (Pind *et al.*, 2003), while the mositure content influence the choice of digestion technology (wet, semi wet or dry). Finally, the VS amount given an idea of the organic substance content in the anaerobic digestion process.

The POME sludge appeared with 6.97 regarding the pH value and the moisture content with 91%. The elemental analysis confirmed that the sludge are very high in oxygen, which represents more that the 50% and present smaller carbon content 26.6%, hidrogen with 4.98% and nitrogen 5.66%. Due to the organic nature of the teatted sludge, a very high content in VS is common in the sample.

Sample	*Elemental analysis*					pH	M* %	C/N ratio	VS %
	C	H	O	N	S				
POME Sludge	26.57	4.97	61.78	5.66	1.05	6.97	90.72	5.0	60.10

**M (moisture content %), VS (volatile solid)*

Table 2:The results of the physical-chemical charaterization of POME sludge sample.

The elemental analysis results showed the estimation of the molecular formula that describe in POME sludge. Since the substrate has organic source, with using general chemical formula is $C_aH_bO_cN_dS_e$, depending on C, H, O, N and S content. The contribution of sulphur can be considered negligible in samples, since it represents less than 1.5%. The coefficients a, b, c, d (Table 2) was obtained as the approximated ration of each component. Molecular formula is applied to evaluate the theoretical biogas (B_{th}) and methane (M_{th}) specific of sludge.

In this case, the result was showed the biogas value with consistent with methane production, 0.50 m^3vs and 0.13m^3vs. Indeed, the elemental analysis significantly shows that coloration between carbon and oxygen content. It was represented the stability of the organic matter that help microorganism to digested and release consistent gases in the substrate.

POME sludge (dry basis)	Elemental analysis	coefficients	Molecular formula	Biogas yield	Methane yield
C_a	26.57	12.0			
H_b	4.97	1.0	$C_{12}H_1O_{16}N_{14}$	0.18 m^3VS	0.15m^3VS
O_c	61.78	16.0			
N_d	5.66	14.0			

**the sulphur content was not considered because it is assumed negligible (1.05%).*

Table 3:Theoretical biogas (Bth) & methane (Mth) yield.

Based on the table above (Table 4), the consequence of this hypothesis is that the biogas and methane yields result overestimated and the error increase as the difference between TS and VS content. Gas yields have been multiplied by the VS content (expressed by the VS/TS ratio), in order to obtain a more realistic (Roati*et al.*, 2012)

Sample	VS/TS	$*B_{th}\ [\frac{m^3}{kgvs}]$	$*M_{th}\ [\frac{m^3}{kgvs}]$	$\frac{m^3CH4}{m^3biogas}\ (\%)$
POME Sludge (Dry basis)	60.12 (38.88%)	0.18	0.15	83.33

Table 4: Biogas and methane yield adjusted account VS/TS ratio.

POME sludge was taken in the scanning electron microscope for physical characteristic and structure contributes for methane and biogas yield (Figure 1).Pores were represented a structure of remaining solid particle and fiber that still remain in the POME sludge. Observation was indicated also dissolved organic matter and other element. Pores contribute as the activated sludge used for methanogens. It also plays a significantly role in physical of the membrane from POME sludge (Clark et al., 1991).

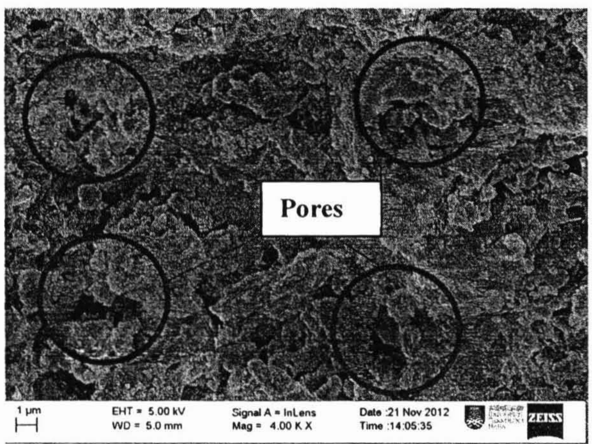

Figure 1: FESEM micrograph (Magnification 4000x) POME sludge structure in dumping pond.

Based on this study the methane emission in the dumping ponds at FeldaJengka 8 Palm Oil Mill could be estimated by using methane yield. By calculating per cubic meter and square meter could estimate quantity of methane emission on that area. With biogas and methane yield was 0.18 m^3/kgVS and 0.15 m^3/kgVS. This accounted for the methane emission was 2.92 m^3/ha. As the result, was demonstrated that for nine dumping ponds in FeldaJengka 8 Palm Oil Mill potentially produce about methane emission about 27 m^3 of Methane.

Financial data

The financial data of the biogas production and biofertilizer project is shown in Table 5.

Biogas Production Parameters and Assumptions	**Value (RM million)**
Capital Expenditure (RM) Modification of eight open anaerobic tank into, closed digestion tank, gas storage tank, pump, compressor, flare, heat exchanger, gas engine for 1.2MW, building, interconnection national grid (3km from the mill)	7.42
Annual Operation & Maintenance Cost (RM) Salary engineer, technician, operators, repair and maintenance	0.17
Annual Revenue from power produced	
- Electric sale	0.2
- Certified emission reductions (CER) sale	1.4

Biofertilizer **Parameters and Assumptions**	**Value** **(RM million)**
Cost of development Building (open windrow with roof), Run-off water retention, roller dryer, loader, sieve, packaging , pump	5.0
Annual Operation & Maintenance Cost (RM)	0.5
- Salary for worker (40)	
- Repair and maintenance	
- 200, 000 l of petrol	
Annual Revenue from power produced	
- Biofertilzer compost	19
- Certified emission reductions (CER) sale	0.9

Table 5: Financial data of the biogas production and biofertilizer project.

Project IRR has been chosen as financial indicator for the financial analysis of the project activity. The project IRR has to be compared with a benchmark rate of return to demonstrate the additionally of the project. Accordingly, recommendation was the development for set-up bioreactor.

The table 5 illustrate the financial analysis for the project activity with and without CDM. As shown, the project IRR without CDM related incomes is much lower than the IRR considered as a benchmark (15%). Therefore, indicates that the project without CDM is not financially attractive. The financial analysis indicates the IRR with or without CDM estimates 16% and 1%, and this investment expense can be paid back within 5 years. The value of IRR is higher than the benchmark, which indicates that the technology is financially attractive but with CDM approaches. If without CDM project showed a business-worthy proposal for financial support

Item	Biogas production without CDM	Biogas production with CDM	Biofertilizer with CDM	Biofertilizer without CDM
NPV (RM million)	0.06	0.9	0.6	0.01
IRR (%)	1	16	14	0.2
PBP (year)	8,2	5	5	7.5

Table 6: Financial analysis for biogas production and biofertilizer at 12 year project term with and without CDM.

Discussion

It was categorized the optimal pH range for methane production bacteria (6.8-7.2) (Rajeshwari et al., 2000). Anaerobic reactions are responsibility in the sludge digestion process. It was involved with highly pH depended. The pH of an anaerobic system is typically maintained between methanogen limit to prevent the predominance of the acid-forming bacteria (Rajeshwari et al., 2000).

In addition, the bacteria in the anaerobic digestion process requires micronutrient and trace elements such as nitrogen, phosphorus, sulphur, potassium, calcium, magnesium, iron, nickel, cobalt, zinc, manganese and copper for optimum growth performance (Rajeshwari et al., 2000). Although these elements are needed in extremely low concentrations, the lack of these nutrients has an adverse effect the microbial growth and performance. According to Baharuddin et al.,(2010) stats that methane forming bacteria have relatively high internal concentration of iron, nickel and cobalt.

Field emission scanning electron microscope revealed that the surface condition of the POME sludge sample was initially hard and rough, and the pores were obvious that showed the matured structure and enhance its decomposition process by microbial activity. Smaller particles provide large surfaces are available for microorganisms, resulting in increasing microbial activity, and the anaerobic biodegradability increased (Mshandete et al., 2006).

From the financial analysis and sensitivity analysis have been showed the project is not financially attractive. It could be seen from the above that only power price the moderate condition, the other project activity not yield a positive IRR leave. Therefore the project is imperative to make financially attractive but only fact the CDM benefit.

This study examined the financial analysis viabilities of biogas production and biofertilizer potential projects was based on the information given by the Felda Palm Industries Sdn. Bhd. and the reports from several researchers. A palm oil mill with a capacity of 50 t/hr FFB has the potential to produce either 6.2 GWh electricity from biogas and biofertilizer.

The financial analysis for 12 years project term analysis indicated that CDM gave a significant effect and ensured economic viability for both project with 15% of internal rate return (IRR), RM 0.9 million of net present value (NPV) and 5 year of payback period (PBP). It is concluded that biogas production and biofertilizer provide additional opportunities for palm oil mills to utilize biomass by products actively with additional financial support of CDM. It is advantageous for the palm oil mills to obtain additional profits through utilizing excess biomass. Furthermore, this technology adaption can improve the surrounding environment by utilized treated POME disposal in optimum used.

Conclusion

Anaerobic digestion can be an interesting solution to treat organic waste and to obtain energy from POME sludge. In this study POME sludge, was characterized and their theoretical biogas and methane yields was calculated using the Bushwell and Neave (1930) formula.

As a conclusion, it can be noticed that POME sludge was still remaining substrates with represent amount of potential methane after anaerobic treatment in palm oil mill. Moreover, the sludge was potential can be utilized with by-product such as biogas and bio-fertilizer consist the suitable element for plants growth.

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