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Evaluation of Technological Content of Wastewater Treatment of Palm Oil Mill in Lampung Province, Indonesia

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Abstract

Palm oil industry is the most important economic sector in Lampung Province, Indonesia. There are 13 units of palm oil mills (POMs) operating in Lampung, producing about 1,094,586 tons of palm oil mill effluent (POME) a year. So far, the POME has been treated by the ponding system. However, the system has still caused environmental problems due to greenhouse gas emissions. Methane capture technology of which methane is converted to electrical energy is thus proposed. The objective of this study was to evaluate the conditions of POME treatment technology of POMs in Lampung. Technological content analysis was performed to identify the conditions of technoware, humanware, infoware and orgaware (THIO) being applied at POMs. The results showed that: (1) technological condition of POME treatment at 13 POM's in Lampung was almost equal among state-owned enterprises (SOE's), non-public companies, and public companies, (2) the value of technology contribution coefficient of PTPN V Tandun, as a reference POM unit, was higher than that of the technology contribution coefficient of the POMs in Lampung, and (3) enhancing performance technology elements of technoware, humanware, infoware, and orgaware to apply methane capture technology are absolutely needed by all the POMs in Lampung.

Keywords: THIO; technological content; methane capture; electrical energy

1. Introduction

Palm oil industry is one of the most important economic sector and plays a strategic role in the Indonesian economy, both for now and for the future. Palm oil industry is a source of foreign exchange and also the living source for most of the population. At the present, Indonesia is the largest crude palm oil (CPO) producer in the world. The CPO production in 2011 reached 22.889 million ton from the plantation area of 8.775 million hectares (Directorate General of Estate Crops, 2012).

The chemical characteristics of Palm Oil Mill Effluent (POME) were colloid, viscous, brown or grayish, pH value of 4.4 to 5.4 and has an average COD content of 49.0 to 63.6 g/L; BOD 23.5 to 29.3 g/L; total solids 26.5 to 45.4 g/L and dissolved solids of 17.1 to 35.9 g/L (Mahajoeno et al., 2008). The overall value of POME parameters were higher than that of the threshold standards set by the Ministry of Environment (MENKLH) Indonesia, so that the POME is a potential polluter (Ministry of Environment of the Republic of Indonesia, 1995). Without any effort to prevent or to manage POME effectively, there will be a negative impact on the environment, such as odor, water pollution and contamination to water bodies around the plant, and greenhouse gases which contribute to global climate change (Ahmad *et al.*, 2001).

In Indonesia POME has been generally treated using a relatively simple method by draining and decomposing in ponds (ponding system). By this way, most of the organic materials are decomposed in an anaerobic condition which consequently produces off odor and generates methane gas emissions. Methane emissions contribute to global warming because it is a greenhouse gas (GHG) with a power of 20-30 times more powerful than carbon dioxide (Porteous, 1998).

Due to the great potential and benefits, the development of palm oil industry needs to be encouraged with mitigation of environmental impact through the application of waste water treatment technologies. Therefore, it is necessary to do the analysis of waste water treatment technologies implemented by POM's prior to implementation of methane capture facilities in the future. The objective of this study was to evaluate the content of waste water treatment technology including technoware, hunmanware, infoware and orgaware (THIO) of palm oil mills in Lampung Province.

2. Materials and Methods

Identification and characterization of wastewater treatment units were carried out at 13 palm oil mills where spread over seven regencies in Lampung Province namely: (1) one unit in South Lampung Regencsy, (2) four units in Central Lampung Regency, (3) two units in Way Kanan Regency, (4) four units in Tulang Bawang Regency, and (5) two units in Mesuji Regency. Two POMs are owned by SOE, other two are owned by private public companies (go for public company), and nine POMs are owned by private non public companies.

Benchmarking study for comparison on the best practices of the POME's handling was conducted at PTPN V Tandun Business Unit, Riau Province, which has been implementing methane capture facilities and converts POME into electrical energy. Mahendra (2013) reported that biogas produced from POME has been conducted by PTPN V of Tandun Unit in Riau Province since 2011. PTPN V Tandun unit has been using a covered in ground anaerobic digestor (cigar) technology to process POME into biogas that is for internal use.

Survey was conducted to obtain data and detailed information about POME treatment units, such as the wastewater discharge rate, waste characteristics, technical data of waste water treatment unit, human resources in handling POME, costs, etc. Data collected was classified, tabulated, and analyzed accordingly. Technological content was evaluated by THIO (Technoware, Humanware, Infoware, and Orgaware) analysis with referring to the criteria set out by Smith and Sharif (2007). Based on this analysis, the problems in wastewater treatment of POMs in Lampung Province were identified.

Technometric approach was used to measure the combined contribution of four components of the technology in process of transforming inputs into outputs. The combined contributions were also referred to as the contribution of technology. The coefficient of Technology or Technology Contribution Coefficient (TCC) was formulated as multiplication function according to Smith and Sharif (2007) and Gumbira-Sa'id (2004), as follows:

$$TCC = T^{\beta t} * H^{\beta h} * I^{\beta i} * O^{\beta o}$$

where:

T, H, I, O = contribution of technoware, humanware, infoware, and orgaware.

$\beta t, \beta h, \beta i, \beta o$ = intensity contribution of T, H, I, O to the TCC.

In analyzing the content of technology, two analytical foci were used: the technological content among POMs in Lampung Province and analysis of technological content of POMs in Lampung Province compared to that of POM at PTPN V Tandun Riau Province as a benchmarking reference unit. Analysis of technological content between POMs in Lampung Province was divided into state-owned POMs (2 plants), public private-owned POMs (2 plants), and non-public private-owned POMs (9 plants). To compute technological content, several stages of analysis were carried out, following Smith and Sharif (2007), Gumbira-Sa'id (2004), Panda and Ramanathan (1997).

3. Results and Discussion

3.1. Technological content of POMs in Lampung Province

At present, there was no POM processing its POME into electrical energy in Lampung Province. The process of POME handling was only treating wastewater prior to discharge into water body, or utilizing the wastewater as a liquid fertilizer for land application. Stages of POME treatment in Lampung Province was grouped into several transformation processes as illustrated in Fig. 1.

Wastewater treatment process by POMs is very simple which is basically similar to the process of wastewater handling of other agro-processing industries. The treatment processes are as follows:

(a) Cooling and precipitation process

This process is a process of decreasing temperature of POME and removal of sand, dirt, and grime that are easy to settle. Cooling and precipitation process generally take about 3-5 days. The output of this process will meet the following requirements, fluid temperature of around 30oC-60oC and a little dirt (sand and soil).

(b) Anaerobic digestion process

This process is a digestion step of POME undertaken by anaerobic microorganism. At this stage, there was a conversion of the macro molecules (protein, fats, and carbohydrates) into methane gas. Microbiological anaerobic decomposition is a process in which microorganisms grow and use energy to metabolize organic matters in anaerobic environments and produce methane gas.

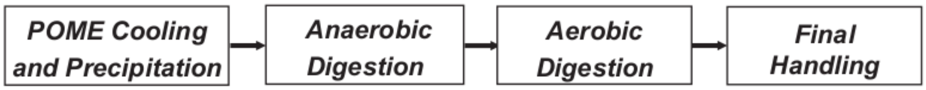

Figure 1. Simplification of POME treatment process in Lampung Province

Table 1. Upper limit (UL) and lower limit (LL) of degree of sophistication of technology components at POMs in Lampung and PTPN V Tandun

Technology Components	The degree of Sophistication				Remarks
	Lampung POM		PTPN V Tandun		
	LL	UL	LL	UL	
TECHNOWARE					
Cooling and precipitation	1	3	1	3	POMs in Lampung and PTPN V Tandun, operated simple equipment and natural method of cooling and precipitation
Anaerobic process	1	3	4	7	In general, POMs in Lampung leave the waste open in the ponds of 5 m depth, while at PTPNV Tandun methane was captured by using plastic covers of the lagoon.
Aerobic process	1	3	1	3	Manual Equipment and simple process were applied at both POMs in Lampung and PTPN V Tandun
Liquid Waste Utilization	4	6	4	6	The effluent was drained and used for *land application*
HUMANWARE					
Employee	1	3	1	3	In general, workers and supervisors of POMs in Lampung and PTPNV Tandun have been adapting and improving skills, while executives at POMs in Lampung have lower capacity in methan capture technology than the executives at PTPN V Tandun Unit.
Supervisor	1	3	1	3	
Executive manager	1	3	4	6	
INFOWARE	4	7	4	7	The Information technology in POMs Lampung was similar to that was used in PTPN V Tandun Unit.
ORGAWARE	4	6	7	9	Liquid waste management organization in the POMs in Lampung was not clearly established, whereas at PTPN V Tandun it was clearly established.

(c) Aerobic process

At this stage, the oxygen is absorbed by water molecules, volatile gases are evaporated, and microbes requiring oxygen are activated. The output of this stage will increase in dissolved oxygen and the decrease on the values of BOD and COD.

(d) Liquid waste utilization stage

Currently, the process of POME utilization is limited to the practice of so called the land application. The land application was done by pumping POME into plantation irrigation system. POME is a source of water irrigation as well as organic fertilizer.

3.2. Technology content of POM in Lampung Province compared to reference benchmarking unit (PTPN V Tandun)

3.2.1. Degree of sophistication of technology components of liquid waste treatment

To determine the lower limit (LL) and upper limit (UL) of the degree of sophistication of each technology component, a scoring method was used. In the case of wastewater treatment in POMs in Lampung Province and POM in PTPNV Tandun, the calculated

Table 2. Technological content of liquid waste treatment of POMs in Lampung Province

No	Technology Components	Lower Limit (Lti)	Upper Limit (Uti)	SoA (Sti)	Normal Contributions (Ti)	Weight	Total Contributions
I	***TECHNOWARE***						
1.1	Cooling and Precipitation	1.20	3.20	0.28	0.196	0.10	0.24
1.2	Anaerobic process	1.20	3.20	0.09	0.154	0.50	
1.3	Aerobic process	1.20	3.40	0.34	0.216	0.20	
1.4	The end of the waste handling process	3.60	5.60	0.40	0.489	0.20	
II	***HUMANWARE***						
2.1	Worker	1.20	3.40	0.36	0.221	0.20	0.28
2.2	Supervisor	1.40	3.40	0.62	0.293	0.20	
2.3	Manager/ Executive	1.60	3.40	0.62	0.302	0.60	
III	***INFOWARE***	3.40	6.20	0.27	0.462	1.00	0.46
IV	***ORGAWARE***	3.60	5.80	0.33	0.480	1.00	0.48

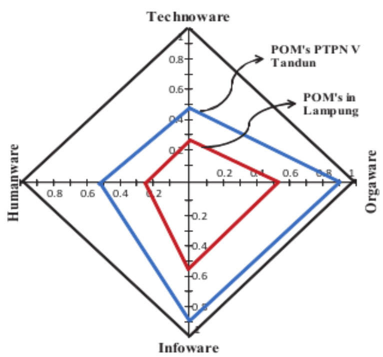

Figure 2. Diagram of THIO of POM’s in Lampung and PTPN V Tandun

Table 3. Technological content of liquid waste treatment of POM at unit of PTPN V Tandun

No	Technology Components	Lower Limit (Lti)	Upper Limit (Uti)	SoA (Sti)	Normal Contributions (Ti)	Weight	Total Contributions
I	***TECHNOWARE***						
1.1	Cooling and Precipitation	1.40	3.20	0.30	0.216	0.10	0.55
1.2	Anaerobic process	3.80	7.40	0.82	0.752	0.50	
1.3	Aerobic process	1.20	3.40	0.34	0.217	0.20	
1.4	The end of the waste handling process	4.00	5.60	0.45	0.525	0.20	
II	***HUMANWARE***						
2.1	Worker	1.20	3.00	0.82	0.297	0.20	0.53
2.2	Supervisor	1.60	4.20	0.86	0.426	0.20	
2.3	Manager/ Executive	4.20	6.00	0.88	0.643	0.60	
III	***INFOWARE***	4.00	6.60	0.37	0.551	1.00	0.55
IV	***ORGAWARE***	6.60	8.20	0.59	0.838	1.00	0.84

results of LL and UL for each technology component are presented in Table 1. It shows that the liquid waste treatment unit was much better in the anaerobic pool technology and facilities, since POM at PTPN V Tandun has a methane capture facilities for electrical energy generation.

3.2.2. State-of-the-art and technologycal content of POMs in Lampung and PTPNV Tandun

State-of-the-art of each technological component was scored by the experts through set criteria. The results of determining state-of-the-art and the calculation of technological content in POMs in Lampung Province and PTPNV Tandun can be seen in Table 2 and Table 3.

The calculated results in Table 2 and Table 3 are presented in the THIO diagram (Fig. 2), showing that there was a gap between THIO values of POMs in Lampung and PTPN V Tandun. The diagram shows that in order to employ methane capture technology for electrical energy generation, the POMs in Lampung Province should enhance technoware, humanware, infoware, and orgaware capabilities accordingly, prior to the establishment of methane capture facilities in POMs in the near future.

In addition, a cyberspace-embodied component, named cysnetware should also be considered to be implemented in POME's handling and utilization. Cysnetware rides on the back of internet-based communications technologies. The ability for electronic communications has far transcended exchange of data and information. To facilitate innovative idea generation and their implementation, cysnetware recognizes the tremendous power of the digital media for global collaborations amongst people as well as for global collaborative processes (Sharif, 2012).

4. Conclusions

The technology content of waste water treatment of POMs in Lampung Province was almost equal among state-owned enterprises (SOEs), private own companies that have gone public, and private companies that have not gone public. Value of TCC (technology contribution coefficient) of PTPN V Tandun which has been implementing methane capture technology for electrycity generation was higher (technoware 0.55; humanware 0.53; infoware 0.55; and orgaware 0.84) than that of POMs technology content in Lampung Province (technoware 0.24; humanware 0.28; infoware 0.46; and orgaware 0.48). The increasing capabilities of technoware, humanware, infoware, and orgaware were absolutely required by all the POMs in Lampung Province to implement methane capture technology for electrical energy generation in the future.

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