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Reducing the greenhouse gas emission from palm oil Industry

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ABSTRACT

Indonesia is the biggest palm oil producer in the world. Palm oil mill is not only producing crude palm oil, but also other products, i.e., palm kernel oil (PKO), liquid waste or palm oil mill effluent (POME), oil palm empty fruit bunch (EFB), oil palm shell, and oil palm fiber. POME treatment with open lagoon technology and EFB dumping in the plantation as mulch are the biggest contributor to the total greenhouse gas (GHG) emissions. Methane emissions from POME and EFB dumping are around 77 % of the total global warming potential (GWP) in CPO production. The objective of this study was applying life cycle assessment (LCA) to compare and evaluate POME treatment, and EFB utilization to reduce the emission of the palm oil industry. The main alternative technologies were EFB composting technology and POME biogas technology. Biogas technology consists of 3 types of combination referring to final effluent from the biogas reactor was unacceptable when it directly releases to the watercourse. The following technologies for biogas technology were composting, membrane technology, and land application. The LCA system boundary was from gate to gate. To estimate the environmental impacts of these technologies, this study used the unit of per ton fresh fruit bunch (FFB) as a functional unit. Among the technologies, biogas integrated with composting technology was higher for reducing GHG emissions in the palm oil industry. Around 167.31 kg CO_2 equivalent of GHG reduction potential per ton FFB processing could be achieved. This summary could help the Indonesian government to reduce GHG and make more environmentally friendlier POME as a by-product.

Key words : *Palm oil mill effluent, Open lagoon, Composting, Biogas, Greenhouse gases*

Introduction

Palm oil contributes greatly to the economies of Indonesia and Malaysia. Indonesia and Malaysia contribute 85% of the global production with a total plantation area of 14 million hectares, more than 715 factories and 106 refineries (refineries), further in 2017 Indonesia's export value reached about 23 billion USD. Palm oil is one of the world's most rapidly expanding equatorial crops. Indonesia and Malaysia are the two largest oil palm producer countries and are rich with numerous endemic, forest-dwelling species (Rupani *et al.,* 2011). BPDPKS (2018) in a press release announced that Indonesia's overall palm oil exports (CPO and its derivative products) increased by 8% or 31.18 million tons in 2017, increasing to 34.71 million tons in 2018.

Palm oil mill (PKS) is still of the World's attention due to environmental problems which as solid and liquid waste produced during the CPO processing at the mill (Choo *et al*., 2011) using a yield of 20.7 ton oil palm fresh fruit bunches (FFB)/ha, the results showed that the production of 1 ton of FFB produced 119 kg CO_{2}-eq. The production of 1 ton of CPO at a mill without and with biogas capture emitted 971 and 506 kg CO_{2}-eq, respectively. For the production of 1 ton of refined palm oil in a refinery that sourced the CPO from a mill without biogas capture and with biogas capture, the GHG emitted was 1,113 kg and 626 kg CO_{2}-eq, respectively.

POME is the largest amount were 0.64 m^3 per ton of processed FFB. The source of POME at the palm oil mill comes from the mud separator (0.39 m^3), hydrocyclone washing (0.243 m^3), and the sterilizing condensate (0.243m^3). Maintain the majority of POME by applying open lagoon technology. Furthermore, in Indonesia, waste density in the form of oil palm empty fruit bunches (EFB) is estimated to reach 31 million tons in 2017 (BPDPKS, 2018). POME treatment with open lagoon technology and EFB disposal in plantations (for mulches) is the easiest and cheapest method of disposal, whilst it also the biggest contribution to total greenhouse gas (GHG) emissions. EFB dumping and POME open lagoon treatment is estimated to contribute 245 kg CO_{2}-eq per ton FFB compared to 7.4 kg CO_{2}-eq per ton FFB when EFB and POME are involved in the composting process and returned to the plantation (Norhasmillah *et al.*, 2013). Methane emissions from POME and EFB stockpiles have around 77% of the total global warming potential (GWP). Especially for the treatment of POME with open lagoon technology it has 7 kg of methane per ton EFB (Stichnothe and Schuchardt, 2011). Recently, composting and biogas in POME processing has developed in the palm oil industry. But the importance of development in the treatment of POME with alternative technologies was minimize environmental impact. In understanding the environmental impact the need for a comprehensive analysis through a holistic approach with all the parameters involved in the system.

Life Cycle Assessment (LCA) is a holistic and general tool used to assess the environmental aspects of product or technology design. LCA can also be a tool to assess aspects of GHG emissions from various technologies related to products as well as to be used to identify technologies that are environmentally friendlier in an environmental friendly labeling program. LCA has successfully evaluated the environmental impact of various products or services throughout the life cycle. At the international level, ISO 14040-14048 explains and provides principles and frameworks regarding LCA.

This study aims to apply a life cycle assessment (LCA) to compare and evaluate alternative POME treatments, and EFB utilizes to reduce the emissions of the palm oil industry. One of the main alternative technologies is a combination of EFB composting technology and POME biogas technology. POME originating from COLT biogas still needs to be treated before disposal, so it is proposed for composting, land application and technology membrane as a final treatment.

Methodology

In this study, LCA was applied to assess the different POME technologies following the ISO 14040 series. LCA can estimate the environmental aspects of alternative technology at every phase of the life cycle. The environmental aspects including the impact on the environment, including depletion of natural resources, energy consumption, water, air, and land emissions respectively.

Goal and scope of the LCA

The goal and scope of this LCA focus on the quantification and comparison of the total environmental impacts of COLT-Composting and COLT-Biogas. The study also includes the consumption of material and energy, such as residue, diesel fuel, and electricity. Sustainability aspects and parameters determined by identifying the elementary input and output that defect the system boundary. Global warming, acidification, and eutrophication are considered as the impact categories.

System boundary and functional unit

The system boundary for LCA is shown in Fig. 1. Gate to gate boundary was used in this study for each combination of technology selection. To standardize mass and energy balance, it was assumed that whole alternative technologies were set up at the same location of palm oil mill in North Sumatra, Indonesia. The plant located close to the mill with the maximum distance from the chopping machine was about 1 km. It was used for diesel fuel consumption and emission estimation calculation. The total electricity demand of whole alternatives came from the palm oil mills which electricity generated uses palm fibers and palm shells as fuel. Data outside the system boundaries are not included in the analysis and downstream activities such as FFB production and transportation from the plantation, the mill, infrastructure, and capital goods distribution and use were not considered in this study. To estimate the environmental impacts of these technologies and total system-wide flows, this study used a unit of per ton fresh fruit bunch.

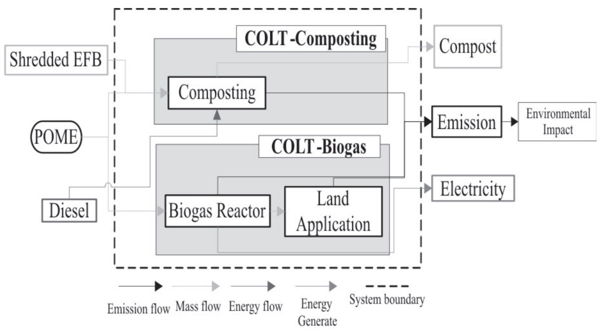

Fig. 1. System boundary

The system boundaries for comparative POME treatment technologies were different involving four the combination of alternative technologies. The raw material inputs were POME at whole alternative technologies and shredded EFB for composting, whilst diesel as fuel at composting and biogas technologies, the material outputs or as final gate were depending on the type of combination of alternative technologies. The final gate for the COLT-Composting was compost product and the COLT-Biogas was electricity. Some assumptions for the COLT-Composting process were POME and EFB amount which is a balance or no excess of POME, no emission run-off water emission since leachate recirculated to composting process and use concrete material for composting land, mechanical aeration for composting by turning the compost periodically with turner machine that powered by diesel fuel. Moreover, electricity for chopping EFB into small pieces before used it for composting. The electricity supplied from a mill that generated from existing palm oil mill boilers biomass. This energy is considered carbon neutral and not as increasing emissions. Whereas, during the COLT-Biogas process, there is no leakage on the biogas reactor related to liquid flow.

Results and Discussion

Mass and energy involve

Alternatives in POME processing were an open lagoon, COLT composting and COLT biogas. This treatment process was summarized in energy units and measured in units of kWh/ton FFB. The open lagoon was an existing POME treatment technology that contains 0.64 ton of POME per ton of FFB and no EFB is processed around 0.21 ton of EFB per ton of FFB. COLT-composting technology will convert POME and EFB into 0.11-ton compost per ton of FFB by COLT-composting technology (Fig. 2). However, COLT-Biogas contains about 15 tons of treated POME per ton of FFB and the processed EFB around 0.21-ton EFB per ton of FFB. COLT-Biogas converts treated POME and EFB to produce electrical energy of around 35 kWh per ton of FFB. The high electrical energy produced in COLT-biogas is due to this technology being an effective technology in processing palm oil mill effluent to produce biogas in greater quantities. Besides this technology, it is always controlled so that the anaerobic organic decomposition process can be regulated, both composition, microbes and temperature to get maximum results with lower BOD levels.

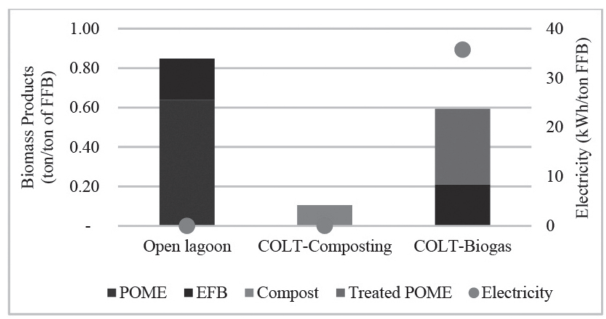

Fig. 2. Mass and Energy involve

According to (Yoshizaki *et al*., 2013) compost production using grated EFB and POME anaerobic sludge obtained from anaerobic digesters is equivalent to 579 tons of nitrogen, 151 tons of phosphorus and 761 tons of potassium respectively. A plant with a capacity of 54 tons of fresh fruit bunches (FFB) per hour has the potential to produce 8.2 GWh of electricity per year using biogas captured during anaerobic treatment from POME. Integrated technology was a more attractive solution compared to the case when palm oil mills install biogas energy or compost technology individually. Integrated technology can still survive economically, which can be a good solution for sustainable management of the palm oil industry in the near future.

Basri *et al.* (2010) on of the improved biogas production from POME is biomass sedimentation condition as applied for the scaled-down anaerobic treatment was able to improve anaerobic treatment of POME. This can be observed from the improvement of the biogas production rate obtained in the mix and settle system, i.e. 2.42 m^3/m^3 of reactor/day at high OLR (6.0 kg/m^3/day). This value was higher as compared to the value reported previously (Yacob, 2005) which was 1.3 m^3/m^3 of reactor/day using a 500-m^3 bioreactor. Moreover, the methane production rate achieved with biomass sedimentation in the 50-L bioreactor was comparable to that obtained in the 500-m^3 bioreactor. Despite the biomass sedimentation improving the biogas production, there was a signicant amount of CO_2 present in the system, which might be due to the shift of acid producer and methanogen ratio at high organic loading.

According to Hamna *et al.,* (2017) that the processing of POME is biological that each ton of POME can produce around 28 m^3 of biogas and around 2.4 tons of methane gas can be reduced in one year which is equivalent to 3.4 million liters of diesel and an estimated energy generated is 13,600 MWh of electricity.

Potential for global warming

The GWP for each technology is calculated using the proportional allocation method with contributions based on raw material inputs and are expressed in kg CO_{2}-eq per ton of FFB. The main contributor to GWP is methane from POME and EFB stockpiling. The GWP for palm oil mill effluent can be reduced from 245 kg CO_{2}-eq per ton FFB to 5 kg CO_{2}-eq per ton FFB due to reduced methane emissions and nutrient recycling. Composting with POME and EFB leads to considerable recovery of nutrients, alongside a reduction in GWP. Among these technologies, COLT composting is more environmentally friendly than other COLT-Biogas, as measured by reducing GWP (Fig. 3). COLT composting has 18.79 kg of CO_{2}-eq per ton of FFB GWP lower than the COLT-Biogas GWP of 41.07 kg CO_{2}-eq per ton of FFB. Approximately 167.31 kg of CO_2 is equivalent to the potential reduction of GHG per tonne of processed FFB can be achieved by applying this technology. 89.67% of GWP can be reduced based on existing technology that uses open lagoon technology. COLT biogas technology can only reduce GWP emissions by 77.3% per ton of FFB production. Produced wastewater will be treated in ponds processing at the open lagoon while a compound of methane and carbon dioxide, in large amounts, are released to the atmosphere caused a greenhouse effect or global warming.

According to Stichnothe and Schuchardt (2010), the composting process reduces not only environmental burdens; it also leads to net environmental benefit regarding most environmental impact categories, in examples as acidification potential, eutrophication potential, ozone layer depletion potential, etc, due to the avoided emissions from inorganic fertilizer production. The recovery of nutrients in EFB can be achieved by solely returning it to the plantation, but only the combined treatment of EFB and POME allows nutrient recovery from POME while methane emissions from pond systems are avoided simultaneously. The fermentation of POME to produce biogas reduces environmental burdens when operating under best practice conditions. However, fugitive biogas emissions of more than 2% reverse that beneficial effect. However, this alternative has the potential to produce electricity and compost production (Nasution *et al.,* 2017). As additional, according to (Zulkifli *et al.,* 2010) one way to reduce environmental impacts is to increase FFB yields through the use of high-yielding oil palm planting materials that result in increased fruit production, by applying more sources of organic nitrogen fertilizer and utilizing palm oil processing plant ponds. POME which is rich in nutrients or uses compost (empty fruit bunches and POME) as fertilizer. Based on LCA research (Chiew and Shimada, 2013) that another technology that can be used to reduce emissions at EFB is CHP combined heat and power (CHP), which is based on sensitivity analysis shows that raw EFB for electricity generation can produce relatively high energy.

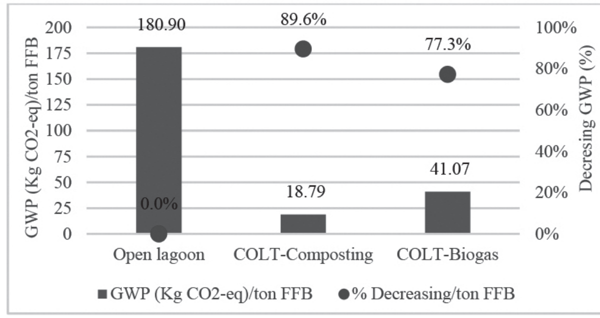

Fig. 3. Global warming potential

Eutrophication Potential (EP) and Acidification Potential (AP)

Acidification increases mobilization and leaching behavior of heavy metals in soil and exerts adverse impacts on aquatic and terrestrial animals and plants by disturbing the food web. Eutrophication is a phenomenon in which inland waters are heavily loaded with excess nutrients due to chemical fertilizers or discharged wastewater, triggering rapid algal growth and red tides. Such acidification and eutrophication are the main causes of air pollution, red tide phenomena, and deterioration of reinforced concrete structures. As a result, surface water, groundwater, and soils are acidified in ways that cause devastation of forests and many shelled animals. The increasing damage to reinforced concrete structures, which are highly resistant to alkali, is the result of a chemical attack by nitrogen oxide (NO_x) and sulfite gas (SO_2) contained in acid rain (Kim and Chae, 2016). EP considers the enrichment of nutrients which caused an increase in biomass production in soil and water ecosystems as well as dramatic reductions in oxygen mass fractions. The EP is calculated by considering and contributing NO_x and PO_4 based on the COD concentration of POME. There are no EP results on COLT-Composting technology because there is no soil and water nutrition in this technology. The EP index produced by COLT-biogas is 0.11 kgPO_4-eq per ton FFB. The low potential of eutrophication will produce good water quality and has no impact on the life of aquatic biota.

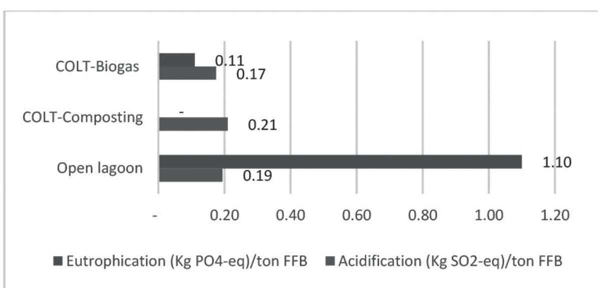

Fig. 4. Eutrophication Potential and Acidification Potential

AP is the impact of changes in acid and basal balance in soil and water bodies due to contamination by SO_2, NH_3, NO, and NO_2 (Chan *et al.*, 2016). NO_2 is the emission from the combustion of diesel fuel also contributes to the AP. For acidification in this study, COLT composting was a higher AP index that released 0.21 kg SO_2-eq, followed by the open lagoon and COLT-Biogas by 0.19 kg SO_2-eq and 0.17 kg SO_2-eq.

Conclusion

In this study, the environmental impact evaluation was carried out to identify alternative POME treatment technologies. The LCA evaluation identified that composting COLT had 18.79 kg CO_2-eq per ton of FFB GWP lower than the COLT-Biogas GWP 41.07 kg CO_2-eq per ton FFB. Approximately 167.31 kg of CO_2 is equivalent to the potential reduction of GHG per tonne of processed FFB can be achieved by applying this technology. COLT biogas reduces GHG emissions by 77.3% per ton of FFB production and there are two types of products from COLT Biogas namely electricity for energy production and compost for fertilizer. Furthermore, the potential for eutrophication in COLT-Biogas is lower than the open lagoon of around 0.11kg PO_4-eq/ton FFB. Recommendation from this research is one way for palm oil mills to conduct industrial waste processing which is more environmentally friendly.

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