Technical problems of wastewater treatment plant in crude palm oil industry
A case study in PT Socfin Indonesia-Kebun Sungai Liput, Nanggroe Aceh Darussalam Province

Y V Paramitadevi and Rahmatullah

1 Diploma Program of Bogor Agricultural University, Kumbang Street no 14, Bogor, Indonesia,
Email: vega_paramitadevy@yahoo.com

Abstract. Crude palm oil produced in Indonesia has already been known as the largest in the world. Unfortunately many of palm oil factories (CPOF) spread out in Indonesia have not good wastewater treatments (WWTP) yet. PT Socfin Indonesia, as an example, which is located in Aceh Tamiang Regency, still has BOD contained in its final effluent of the wastewater treatment plant more than 150 ppm. In fact, the capability and capacity of WWTP in PT Socfin are 192 m³ per day. Because of improper operational and maintenance of the WWTP, the technical problem are accumulated, such as, increasing the deposition of sludge and decreasing the retention time. The following affect is the treatment process is not going well and the quality of effluent is getting worse. The objective of this paper is to solve the technical problems by means removing the deposition of sludge periodically and fixing floating aeration in the aerobic pond. Method using for this paper is survey and wastewater sampling. A recommendation of the wastewater treatment system has been proposed after average BOD from WWTP outlet is defined 158 mg/L. The recommendation has seven processes including oil separation, neutralization, closed tank anaerobic digester equipped with gas holder, extended aeration, settling tank, sand drying bed and land application.

1. Introduction
Oil palm (*Elaeis guineensis*) is a versatile monoecious oil bearing plant, its distribution is restricted to tropical regions of the world, particularly in Indonesia and Malaysia [1]. The global production of palm oil has been more than doubled every 10 years, and by 2020, it is expected to increase to 78 million tonnes [2]. The different steps of the palm oil extraction process generate various types of waste by-products including solid waste such as oil palm shell (OPS), fibres, empty fruit bunches (EFB), palm oil clinker (POC) and palm oil fuel ash (POFA) accompanied by palm oil mill effluent (POME) the most significant pollutant in the form of wastewater, if not managed properly, it could be disastrous impact on the environment [3,4].

Raw POME is a colloidal suspension containing 95-96% water, 0.6-0.7% oil and 4-5% total solids including 2-4% suspended solids [5]. The suspended solids are mainly consist of debris from palm fruit mesocarp generated from three main sources, (1). sterilizer condensate, (2). clarification wastewater, and (3). hydrocyclone waste [3,4,6,7,8]. Consequently, about 0.9, 1.5 and 0.1 m³ of
POME will be generated from sterilizer condensate, clarification wastewater and hydrocyclone waste for each tonne (1.13 m³) of crude palm oil processed [5,8]. Thus, it was estimated that in year 2014, 21.35 million m³ tonnes of POME was generated from Indonesian palm oil mills base on the total CPO production of 28.9 million m³ tonnes. Figure 1 shows percentage of Indonesian CPO production in year 2014.

Although POME is a non-toxic liquid waste with unpleasant smell, its COD and BOD value are high enough to cause serious pollution and environmental problem to the rivers. Table 1 shows a typical characteristics of POME and discharge limits for POME discharge into water sources in Indonesia. Nevertheless, many palm oil mills are still unable to adhere to the wastewater discharge limits and thus resulting to a dramatic increase in the number of polluted rivers [5,8]. Furthermore, if the POME is discharged without prior purification, the BOD produced daily was estimated to be 9.12 million kg [10]. In other words, if each human being is assumed to produce 14.6 kg annually, this BOD value will be equivalent to the waste generated by 45.6 million people which is nearly 18% from the current population in Indonesia.

Table 1. Characteristics of wastewater to produce the POME\(^a\) and discharge limits of treated POME in Indonesia\(^b\).

| Parameters           | Typical POME | Discharge Limits (mg/ L) | Maximum Value of Pollution Loading (kg/ tonnes) |
|----------------------|--------------|--------------------------|-----------------------------------------------|
| BOD\(_5\)            | 25 000-29 000 | 100                      | 0.25                                          |
| COD                  | 51 000-64 000 | 350                      | 0.88                                          |
| TSS                  | 18 000-23 000 | 250                      | 0.63                                          |
| Oil and Grease       | 6000-7000    | 25                       | 0.063                                         |
| Total Nitrogen       | 750-1200     | 50                       | 0.125                                         |
| pH                   | 4.5          |                          | 6-9                                           |

\(^a\) Lam and Lee [5], Liew et al. [6], Wu et al. [8]
\(^b\) Decree of Minister of Environment and Forestry [14]

Ponding system is the most conventional method for treating POME [6,11], but other processes such as aerobic and anaerobic digestions, physicochemical treatments and membrane filtration may also provide the palm oil industries with a possible insight into the improvement of current POME treatment process. More than 85% of palm oil mills in Indonesia have adopted the ponding system for POME treatment [12,13]. However, few have been put into full scale operation because of the unsatisfactory performance, high capital investment and maintenance cost. The open lagoon POME treatment system covers 10-12 acres of land, along with this; it has various drawbacks as long hydraulic retention ti
me (HRT), foul smell, greenhouse gas emissions, and large occupied area. The existing technologies are unable to consistently meet the proposed stringent biological oxygen demand (BOD) regulatory discharge standard of 100 mg/L to be imposed by the Ministry of Environment and Forestry, Indonesia [14].

PT Socfin Indonesia Kebun Sungai Liput (PT SI-KSL), located in Aceh Tamiang regency, has been operated for more than 15 years. In producing crude palm oil, PT SI-KSL has undergone several processes of rehabilitation and development towards perfection. However, those improvements are still not optimum evidenced by the number of oil content contained in POME is still high. The fatfit pond is unable to recover POME from clarification process. As the result, the BOD loading into POME treatment plant has reached more than 25 000 ppm. In certain circumstances, the output of wastewater, especially BOD is still above government quality standard. Thus the problems which occurs in POME treatment plant in PT SI-KSL should be identified and solved. The ultimate goal of this paper are: (1) identifying technical problems of POME treatment plant of PT Socfin Indonesia in Kebun Sungai Liput, Aceh Tamiang regency, (2) giving best practices of POME treatment plant for PT Socfin and Aceh Tamiang government district.

2. Methods

Methods used in this paper according these following steps:

2.1. Literature Review
In purpose to describe the problems of POME treatment plant at oil palm plantation, it takes at least references about the process of producing crude palm oil (CPO). References on some wastewater treatment system that has already existed in Indonesia and Malaysia are also still needed for comparison.

2.2. Field Survey
The field survey was conducted on February 6th, 2015 in PT SI-KSL, Aceh Tamiang Regency. Secondary data of POME treatment plant was collected for 3 months, from February to April 2015. The survey was also carried out grab sampling of wastewater generated, sampling of the output of POME treatment plant from PT SI-KSL using Indonesia National Standard method no 6989.59:2008 and measuring the depth of ponds.

2.3. Analysis
Primary data obtained from the results of laboratory analysis using Indonesia National Standard method for pH, COD, BOD, TSS, oil and fat parameters and direct observation of wastewater treatment plant are revealed and discussed to identify existing problems in PT SI-KSL. When key parameter of BOD has reached > 150 mg/L, solution or appropriate alternative for PT SI-KSL’s WWTP can be decided.

3. Results

3.1. Field Survey
PT SI-KSL has maximum production capacity 20 tonnes of fresh fruit bunches (FFB) an hour. This plant operates on an intermittent basis, when the demand for CPO increased and the price suited, the plant is operated for 24 hours. In reality, this plant often operates for 16 hours or 2 shifts. CPO production process begins from the sterilization process and continues with threshing palm fruit. Then the fruit has been crushed separately and pressed. After pressing, the impurified liquid oil is accommodated in the clarification unit. Clarification unit consists of three processes, namely filtration, deposition and evaporation. In the deposition unit, oil contained in the upper layer flows into
evaporation process. The clarified oil reached certain standard of CPO is stored in storage tanks. Those process and maintaining machines generate wastewater in huge amount.

3.1.1. POME Quantity and Quality
The amount of wastewater produced about 60 percent of plant’s capacity. When plant capacity is 20 tonnes FFB per hour, the number of POME is about 12 tonnes per hour. Production process is running in 2 shift, which is 16 hours per day. So, the number of wastewater is 192 m³ per day.

The influent quality of wastewater (before fatpit and pre-sedimentation) and effluent quality (aerobic pond) is based on the laboratory analysis in Table 2.

Table 2. Characteristics of wastewater in PT SI-KSL
(April 2014-March 2015)

| Parameters            | Average Influent Discharge (ppm) | Average Effluent Discharge (ppm) | Discharge Limitsa (ppm) | Effectivity (%) |
|-----------------------|----------------------------------|----------------------------------|-------------------------|-----------------|
| BOD₅                  | 31 000                           | 158                              | 100                     | 99.5            |
| COD                   | 25 000                           | 320                              | 350                     | 98.7            |
| TSS                   | 15 000                           | 78                               | 250                     | 99.5            |
| Oil and Grease        | 13 500                           | 24                               | 25                      | 99.8            |
| Total Nitrogen        | 550                              | 6                                | 50                      | 99              |
| Ph                    | 4.5                              | 8.7                              | 6-9                     | 48.3            |

a [14]

3.1.2. POME Exsisting Treatment Plant
POME exsisting treatment plant was built in 1996 considering untreated wastewater with BOD/COD ratio of 0.5 and greater can be treated easily by biological means. Aerobic and anerobic treatment is suitable for POME treatment. In comparison of these 2 treatment methods, the anaerobic treatment can be regarded to be more suitable for POME treatment due to its lower energy consumption. Figure 2 shows flow diagram of POME treatment plant in PT SI-KSL.

Figure 2. Flow diagram of exsisting POME treatment plant in PT SI-KSL
Wastewater from all CPO production process which flows into fatfit tank still has acidic characteristic (pH 4-4.7) and medium temperature (50-75°C). The oil contained in the wastewater will be easily separated in that condition. The fatfit dimension is 3 x 50 m² with 0.8 m depth. Hydraulic retention time (HRT) is 15 hours with remained BOD value is 25,000-35,000 ppm. Wastewater from fatpit tank flows into cooling tank. Capacity of cooling tank is 15 m³ with 1.5 hours HRT. The temperature of wastewater decreases become 38°C which suitable for mesophilic bacteria.

The second wastewater process is anaerobic ponds which are consisted of 3 ponds and operated in sequence. The first is acidification anaerobic pond that has HRT 62 days and dimension 78 x 38 x 4 m³. BOD outlet value from this pond is 1300-2500 ppm. There are 2 circulation pipe coming from anaerobic and aerobic ponds in acidification anaerobic pond. The second is called anaerobic pond with dimension 61 x 32 m² and 4 m depth. This pond HRT is 41 days, BOD outlet level is 500-1100 ppm. Circulating pump in this pond is streamed back to acidification anaerobic pond. The third pond is facultative pond. This pond is an intermediate between anaerobic and aerobic pond with dimension 61 x 32 x 4 m³. The HRT of this pond is up to 41 days. Estimated BOD outlet level is 200-300 ppm with pH is 5 to 6.

The third is aerobic process with dimension of 110 x 100 x 1.5 m³ and HRT 86 days. Aerobic process implemented with floating aerator that served to supply oxygen into the wastewater and switched on for minimal 15 hours a day. BOD outlet level is 150 to 200 ppm.

The last pond is settling pond with dimension of 50 x 32 m² and 2.5 m depth. The HRT is 21 days with BOD outlet level is about 130-150 ppm. Wastewater discharge directly to secondary class of river based on Government Regulation no 82 year 2011, Tamiang River.

3.2. Technical Problems of POME Treatment in PT SI-KSL

3.2.1. Fatpit Pond
Fatpit pond should runs well with HRT of 15 hours. Only little amount of oil that can be refined. Operational process of fatpit definetely has been many of irregularities, based on observation revealed the following things :

- Although operating temperature is about 60°C in fatpit pond, the oil refinery process is still unoptimal. Wastewater flow rate through the pipeline is too fast, so many impurities had not enough time to settle. The real HRT become far below 15 hours. As a result, a lot of emulsified oil in the bottom layer flows into acidification pond.

- Reduced HRT occurs because of hardened sludge on the bottom of fatpit pond. The depth of fatpit is reduced to 50 cm. This condition led to reduce the volume of effective chamber and to decrease the settling process. Treatment management in fatpit pond has not done properly. Moreover, cleaning hardened sludge should be done periodically.

3.2.2. Anaerobic Pond
Pointing from anaerobic pond capacity, the HRT of 3 ponds as can be seen in Table 3 is enough. Even organic loading rate (OLR) value of anaerobic ponds is higher than design criteria, the wastewater can be directly serves as bait for next POME treatment process, the aerobic pond.
Table 3. Comparation of design criteria and existing design of Anaerobic and Aerobic Pond in PT SI-KSL

| Problems             | Anaerobic Ponds | Design Criteria for Anaerobic Ponds | Aerobic Ponds | Design Criteria for Aerobic Ponds |
|----------------------|-----------------|-------------------------------------|---------------|----------------------------------|
| The Depths           | Acidification   | Anaerobic                           | Faculative    |                                   |
|                      | 4 m             | 4 m                                 | 4 m           | 5-7 m for anaerobic, 1-1.5 m for facultative |
|                      | HRT             | 62 days                             | 41 days       | 30-45 days for anaerobic, 15-20 days for facultative |
|                      | COD removal Eff | 98.8 %                              | 97.8%         | 50%                               |
|                      | OLR             | 1.67 kg COD/ m³ day                 | 1.4 kg COD/ m³ day | -                                 |

*a*[5]  

3.2.3. Aerobic Pond  
Aerobic pond made with 1.5 depth and considered for contacting air to wastewater. The deposition of sludge on all the corner of the pond will reduce HRT. Floating aerator at the time of observation is damaged and need to be fixed. In Table 3, HRT of aerobic pond 86 days exceed design criteria which is 24 days. Prolonged 86 days of HRT made treated wastewater become anaerobic. Aerobic process will be optimal using biofilter as media.

However, the aerobic pond was filled with scum which led to decrease HRT. Creation of scum on the surface and body be subject to build-up at the bottom of the pond is main difficulties with this system, which lowered efficiency. So, regular desludging need to do either using submersible pumps or excavator to continue the preferred efficiency.

The ‘dead space’ will lead to volume reduction in each pond. The POME treatment plant of PT SI KSL is not need of energy, which means without stirring, pumping and desludging. The gases produced also smell sting of each the pond. Lack of biogas and CH₄ control is disadvantage of ponding system.

Aerobic ponds made up of earthen structures with no lining at the bottom. This condition will led to groundwater contamination. Aerobic ponds should be constructed with geotextile liner and used biofilter as a means of bacteria-growth.

3.3. Recommendation of POME Treatment in PT SI-KSL  
According to advantages and disadvantages of the ponding system, it is necessary to redesign the process and plant at PT SI-KSL. The process will be dominated by biological processes, although there is physical and chemical process as well.

The first step is oil separation tank which has similar method with fatpit system. Because POME has acid characteristic, the second step is neutralization. The third step is closed tank anaerobic digester. Closed tank anaerobic digester are more efficient in removing COD (>95%) at a lower HRT of 17 days [15]. Closed system also generate biogases which are eventually either converted to elecricity in a
biogas engine (gas holder) or burned into gas flare. This system is also equipped with circulation tank for optimizing and controlling the amount of sludge in digester.

Supernatant from the recirculation tank will flow to extended aeration tank and settling tank. Effluent from settling tank is discharged to land application, mainly for irrigation. Sludge treatment plant is using sand drying bed treatment.

Through digestion and extended aeration processes, the nutrient content particularly nitrogen and potassium will go down through leaching and settling of sludge solids at the plant underneath. This mechanism breaks down complex organic solids for enhancing nutrient uptakes by plants. BOD level will be decrease with these system.

4. Conclusion
Based on field survey and data analysis at PT SI-KSL, the aerobic ponding system processing capacity has decreased due to damaged floating aerator and sludge accumulation. This condition led to decrease COD and BOD removal efficiency, which is only 50%. BOD average is always higher than effluent discharge, 158 mg/L. The ponding system is not operated and maintained well. PT SI-KSL recommend to redesign their POME treatment plant.

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