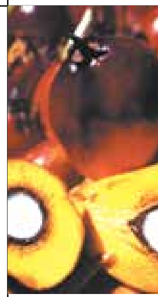
Feature Article



Waste Minimisation for Palm Oil Mills: A Case Study

Ropandi Mamat*; Astimar Abdul Aziz* and Rohaya Mohamed Halim*

INTRODUCTION

The Malaysian palm oil industry has been growing steadily during the past few decades establishing a prominent place in the economy of the nation. In 2014, the land under oil palm cultivation was about 5.39 million hectares in Malaysia with 443 palm oil mills in operation (MPOB Statistics, 2015). The production of crude palm oil (CPO) was 19.96 million tonnes in 2015, contributing to more than 33.15% of the world production of palm oil. However, the production of palm oil also generated a large amount of palm oil mill effluent (POME) at the average production rate of 0.67 t^{-1} FFB processed. Based on the crude palm oil production in 2015, the volume of POME generated was about 99.51 million tonnes. The POME originated from three sources; 1) steriliser condensate, 2) separator sludge or sludge centrifuge, and 3) hydro cyclone wastewater or clay bath used for cracked mixture separation (kernel separation). *Table 1* shows the three POME sources as a percentage of the FFB processed.

TABLE 1. SOURCES OF POME AND THEIR % TO THE FFB PROCESSED

Source of POME	% to FFB
Steriliser condensate	12
Sludge centrifuge wastewater	50
Hydro cyclone/clay bath wastewater	5

Currently, the biochemical oxygen demand (BOD) of the POME is not fully degraded to comply with the minimum proposed requirement of the Department of Environment (DOE) due to the inconsistent BOD values that fluctuate widely when crop quantity or ripeness deviate from normal to abnormal values. This inconsistency of the BOD values can result in non-compliance with the DOE requirement, the environment quality regulators, if the POME is discharged into the water. Most of the mills use open

* *Malaysian Palm Oil Board (MPOB),*
6, Persiaran Institusi, Bandar Baru Bangi,
43000 Kajang, Selangor, Malaysia.
E-mail: ropandi@mpob.gov.my

TABLE 2. CHARACTERISTICS AND CHEMICAL CONSTITUENTS IN POME

Parameter	Mean value	Parameter (mg litre^{-1})	Mean value
pH	4.7	Protein	16 000
Temperature (°C)	85	Phosporus	180
Oil and grease	4 000	Potassium	2 270
BOD_3, mg litre^{-1}	25 000	Magnesium	615
COD, mg litre^{-1}	50 000	Calcium	439
Total solid, mg litre^{-1}	40 500	Boron	7.6
Suspended solid, mg litre^{-1}	18 000	Iron	46.5
Ammonical nitrogen, mg litre^{-1}	35	Manganese	2.0
Total nitrogen, mg litre^{-1}	750	Copper	0.89
Carbohydrate constituents, mg litre^{-1}	10 000	Zinc	2.3

ponding systems for treating the POME as it is relatively an inexpensive system in terms of maintenance. The open ponding system for POME involves a biological treatment system comprising aerobic and anaerobic digestion systems.

Anaerobic digestion degrades or breaks down the organic matters into the simple end products such as methane, carbon dioxide, and water. Even though the treatment cost is comparatively low, it requires long treatment periods that can take up to more than 120 days. However, sometimes the treated POME using ponding system may not comply with the set discharge standard of 100 mg litre^{-1} BOD, especially during peak crop season or when facing adverse issues related to the ponding system. In addition, ponding system generates considerable quantity of biogas consisting of about 40% to 60% of methane which is greenhouse gas (GHG). The methane released from the POME is one of the problems currently faced by the oil palm industry in their efforts to be a competitive and remain a sustainable industry in the world of oils and fats. However, some initiatives are underway to mitigate the methane problems such as by methane recovery or trapping and use it as fuel for electricity generation. Visibly the POME is a thick brownish viscous liquid waste (mixture of water, oil and fine suspended solids) but it is non-toxic as there are no chemical inputs during the extraction process. However, due to the high content of organic loading, by the time it begins to emit its unpleasant odour, the POME pH is around 4.5. This is considered to be highly polluting due to its very high BOD content which is almost 100 times higher than that of the domestic sewage. The characteristic and chemical constituents of POME has been analysed and determined by many researchers and are summarised in *Table 2*. It indicates that POME has a high content of degradable organic matter in the form of suspended solid, oil and grease, carbohydrate constituents and protein.

As the residual oil and grease are generally trapped within the suspended solids, the removal of the suspended solids will actually remove the oil and grease and also some portions of the insoluble matters. The fresh POME containing such high organic components cannot be discharged into any water ways without contributing towards serious water pollution that would have detrimental impact on aquatic life as well as the river ecosystem. In order to address this issue, the government is planning to set up a more stringent discharge standard for POME for its discharge to the water course from the existing 100 ppm to 20 ppm. Thus, the millers need to improve the current treatment methods for POME which would most likely incur additional cost. In

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order to overcome the problem, the waste audit and its minimisation were proposed to be implemented in palm oil mills in Malaysia. Through this approach, the volume of the POME generated could be reduced, thereby reducing the total BOD load in the effluent. This paper is based on a case study conducted at Palm Oil Milling Technology Centre (POMTEC) at Labu, Negeri Sembilan. The case study also proposes the available technological options for waste reduction and elimination. In addition, the economic feasibility of the proposed system was conducted by performing a cost-benefit analysis. This study provides an idea of waste minimisation approach with proven technologies which are economically feasible to be implemented in palm oil mills.

MATERIAL BALANCE OF PALM OIL MILL

The materials balance which represents the input and output of materials for the process is important and essential for conducting and implementing the waste audit and its minimisation. The amount and the flow rate of the main wastewater discharge as well as it pollution load strength needs to be measured and quantified. Based on that, the critical stream with regards to volume of waste and its strength is selected for the waste minimisation. The possible options for cleaner production based on viable technology and economy can be proposed to maximise production efficiency and minimise the waste discharge from the process as well as reduce the production cost. *Figure 1* shows the material balance for the processing of 20 t FFB process per hour, which is based on 1 t of FFB processed. It is clearly shown in the material balance that the solid waste produced from the process are the mesocarp fibre, palm shell and empty fruit bunch (EFB) at 192.5 kg, 52 kg (wet) and 220 kg respectively. Meanwhile, the liquid waste or POME generated is about 547 kg, which is less than an average figure of 67%. Besides solid and liquid wastes, there are also wastages from the heat and evaporation losses that have not been given much attention by millers. Actually, the heat can be recovered for other uses especially for drying the decanter cake or in the case of heat from the boiler, it can be used to heat the boiler feed water.

METHODOLOGY

Waste Minimisation for Palm Oil Mill

There are few measures that can be implemented for achieving waste minimisation in the palm oil industry. These include the water conservation, process modification, source reduction, recycling and reuse. The water conservation is carried out by reducing the amount of water for the process and process modification is by using a cleaner production technology which is able to reduce or eliminate the wastewater from the process. In palm oil mills the potential exits for evaporation of most of the moisture in the POME and condensation so that it can be recycled for process operation.

AUDIT OF PROCESS AND STREAM

In auditing the process and stream for the palm oil mill, there are few viable alternatives or options that can be used which can lead to a cleaner production technology. Since the objectives is to reduce the volume of waste generated as well as it loading capacity or strength, the reuse, recover and recycle of liquid waste can be carried out by water conservation and waste strength reduction.

CRITICAL STREAMS

Steriliser Condensate

Steriliser condensate is coming from the condensation of water vapour either from steam introduced or evaporation of moisture in FFB due to temperature of the steam applied. Based on the material balance at the sterilisation stage, for 1 t hr^{-1} FFB, the amount of steam used is 250 kg. In the steriliser, the evaporation loss is about 170 kg t^{-1} FFB and steam condensate 200 kg t^{-1} FFB (*Figure 1*). The condensate

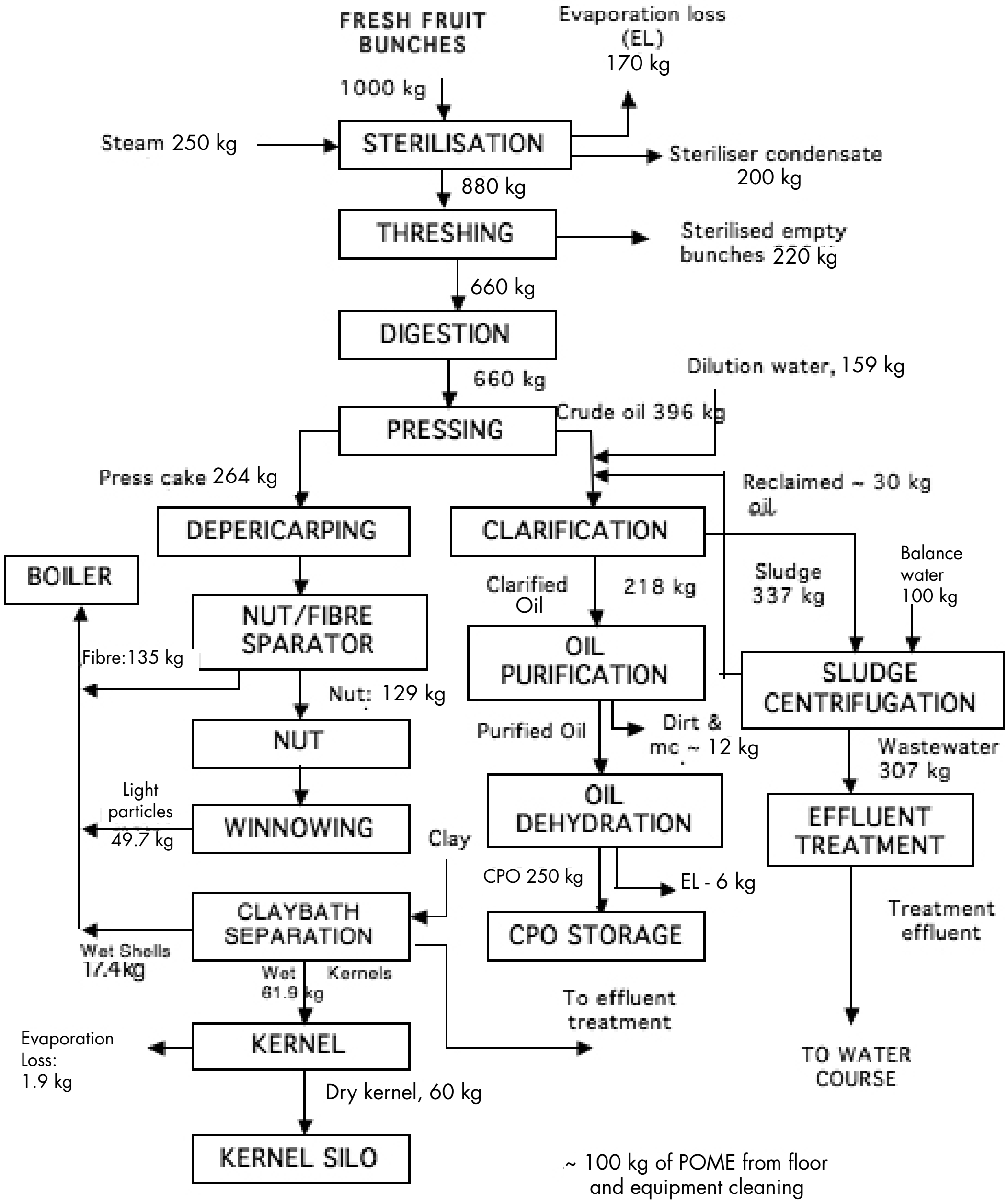

Figure 1. Materials balance for 1 t of FFB processed in palm oil mill.

consists of oil, water, fibrous material and sand. The average amount of oil in steriliser condensate is 3 kg. The flow rate of steriliser condensate is approximately 3 to 4 t hr^{-1} for 20 t hr^{-1} mill capacity. The normal practice is the millers will recover the oil from the steriliser pit and sell it as second grade oil whereas the remaining traces of oil will be discharged to the mixing pond for further POME treatment.

Underflow Continuous Settling Tank (CST)

Figure 3 shows the material balance underflow from the continuous settling tank (CST) when it undergoes oil/waste water separation in a typical stork centrifuge, a popular machine in most of the palm oil mills in Malaysia. The composition of the underflow is mostly made up of the sludge

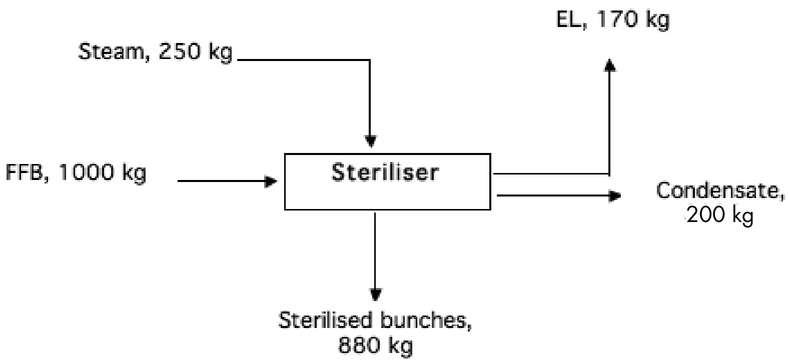

Figure 2. Material balance at steriliser.

and suspended solids with approximately 7% of residual oil comprising un-ruptured cells containing oil as well as small oil droplets below 15 micron sizes that failed to rise up in the vertical clarifier for gravity separation due to its poor buoyancy. The underflow from the CST is normally pumped into an overhead sludge tank from where it is gravity fed into a circular sludge water range (ring distribution system) to ensure even distribution of feed into all sludge centrifuges. The heavy phase of the sludge centrifuge, comprising mostly water and some suspended solids like fibrous material, is discharged out as the main component of the palm oil mill POME. During the centrifugation process, hot water is added for phase dynamic balancing. The mill uses three units of 'Stork centrifuge' for oil recovery from sludge. The volume of the sludge discharged out is measured using a basculator. For a 20 t hr^{-1} mill, the sludge flow rate is 6 t hr^{-1} (6 t hr^{-1} is too low, 40% = 8 t hr^{-1})

Cracked Mixture Separation/Clay Bath

The function of clay bath is to separate the shell and kernel from the cracked mixture. Compared to the hydro cyclone, the claybath gravity separation system has increased the separation efficiency as fragments of kernel can be fully recovered provided that the specific gravity of the clay-bath is monitored and maintained (at 1.16) at regular intervals. After the separation, the kernel and shell are washed with clean water to remove the residue clay that stick to them. The washing water then goes back to the water bath. After recycling a few times the clay bath needs to be renewed when the dirty clay bath is discharged into the clay bath pit. In the clay bath pit, the clay will sink to the bottom, while the supernatant (water) will be discharged into the effluent pond. The clay then will be recovered. The amount of water discharged to effluent from the clay bath is about 28 kg t^{-1} FFB processed, thus for 20 t hr^{-1} mill capacity, the discharge flow rate is 0.56 t hr^{-1}.

RESULTS AND DISCUSSION

Waste Audit and its Minimisation for Critical Streams

Recycling of sterilised condensate (water conservation). Water consumption for palm oil mill could be reduced by reuse/recycling of the steriliser condensate as a substitute for crude oil dilution at the press station. As shown in *Figure 2*, the amount of steriliser condensate together with steriliser exhaust steam is 200 kg t^{-1} FFB processed, whereas the dilution water required for the press is about 160 kg t^{-1} of FFB processed. The proposed treatment system requires a level activated pump complete with wiring and a piping system (*Figure 4*). The pump is used to pump back the oily water to the holding tank at the press station. The pump is provided with level switch, thus it will be activated when the level in the steriliser pit rises up and stop when the level reach the level drops to a set value. This will reduce the man power requirement and at the same time only the top portion of oily water will be pumped up while the bottom which consist of, heavy

particles such as sand, clay, *etc*. would sink to the bottom and require desludging once a while. Meanwhile, the water can be used as dilution water through normal process. By doing this, the fresh water consumption is reduced and at the same time reduces the amount of waste water by 160 kg t^{-1} FFB processed. Besides that it also reduces the strength of the POME since most of the oil in the steriliser condensate is recovered through this recycling process. However, care should be taken to ensure that only fresh steriliser condensate is recycled in order to avoid the deterioration of finished product quality.

Process Modification at the Clarification

In the conventional clarification process, the primary separation of oil from the sludge is achieved in continuous settling tanks using gravity separation. However, in the newer and modern mill set up, two phase decanters has been installed to treat the underflow from the continuous settling tank, combined with sludge centrifuge. Decanter employs high speed centrifugation force to separate the heavy phase (decanter cake) and light phase (oil and water) component based on density differences of each component. The decanter cake has a moisture content of 50% to 70% and it can be used for the composting process or as a fodder for cattle rearing. By removing the solid, the BOD as well as the volume of waste stream can be reduced slightly. Removing the solids also facilitates faster oil separation since the suspended solid and dirt has been removed. The recycling of light phase and the solid removal by the decanter can generate additional income for the mill due to the improved oil recovery and sale of decanter cake. *Figure 5* shows the schematic diagram for two-phase decanter installation.

Process Modification for Hydro cyclone/Clay Bath (Cracked Mixture Separation)

The use of hydro-cyclone or clay bath for cracked mixture separation is known as a wet process which continuously discharges the wastewater. There is a dry separation process called four stage winnowing system for cracked mixture separation developed and promoted by MPOB as an alternative for the wet process. The technology is actually to produce clean palm kernel so that the palm kernel cake obtained from kernel crushing plant will have better quality and fetch a higher price. Palm kernel cake can be commercialised as animal feed. By using the dry separation process, the amount of effluent discharge from kernel plant will be much reduced. The dry separation system consists of a number of equipment: a four-stage winnowing column, a cyclone, a blower fan and an air lock. Each column has been designed with different parameters (*e.g.* air velocity, fan speed, column height, inlet and outlet levels, feeding ratio, *etc.*) in order to achieve the desired shell and kernel ratio separation at each outlet point. The four-stage winnowing column uses forced draught principle instead of induced draught and the air flow velocity is adjusted via the blower (damper) located at ground or an elevated level. Each column is operated by a 25 HP forced draught fan. This approach simplifies the process and ensures ease of control, as well as possesses the ability of eliminating the effluent generated from the

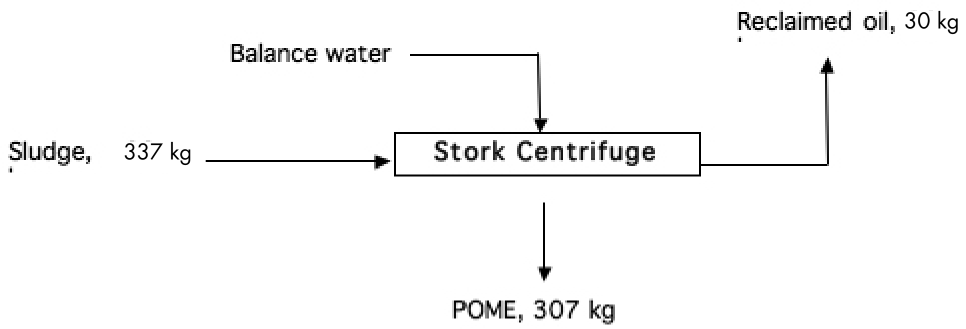

Figure 3. Material balance at stork centrifuge.

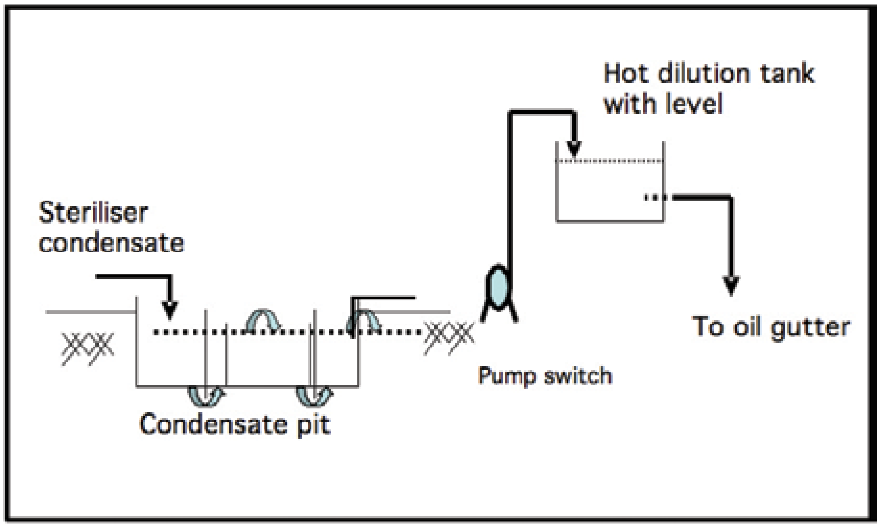

Figure 4. Schematic diagram of recycling steriliser condensate for hot water dilution.

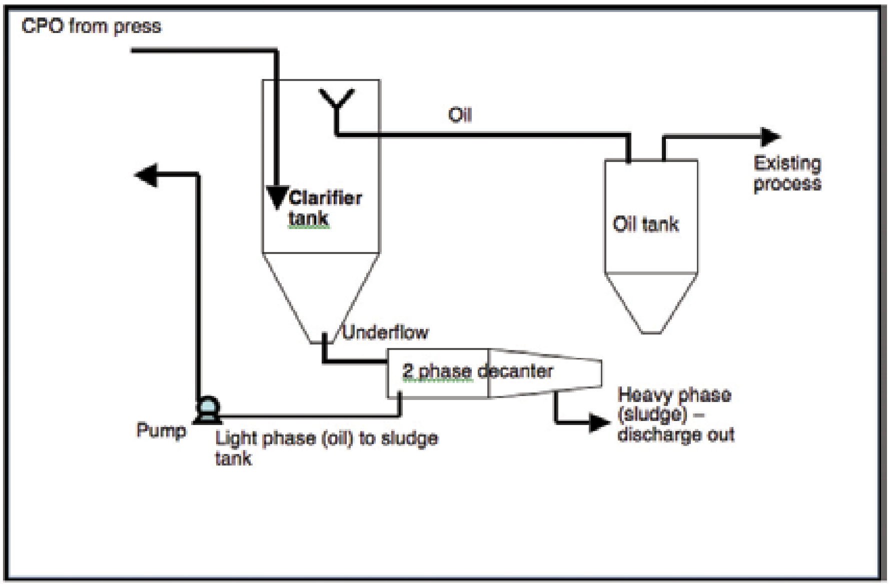

Figure 5. Schematic diagram for two-phase decanter.

wet separation system. The photo of the four-stage winnowing column is shown in *Figure 6*. This technology also produced a dry palm shell thus its usage as a boiler fuel will reduce the possibility of air pollution problems associated with the black smoke emission due to incomplete combustion.

Figure 6. The four-stage dry separation for a cracked mixture.