# Editorial

Most millers are aware that process control is a very important tool for conducting good milling practice. It is verily the ‘eyes’ of the whole process operation. It is of paramount importance for the mill management to ensure that it is not only done regularly but that it is also done with a good measure of zeal and truthfulness, so that the ensuing results accurately reflect the losses and quality of palm products at different stages of process operation. Large plantation companies in Malaysia have well-organised process control departments with a network of routine inspection schedules, carried out by its specialists stationed in their head office. However, this is not replicated by some private companies, as it may be to reduce operational costs. This may be akin to penny wise and pound foolish approach as even for a small mill, the role of process control is something that it can ill afford to totally ignore.

Process control is a fundamental activity in any produce line as only it can effectively guide the personnel in charge to continuously alter the process course to follow the desired targets. If this is not followed religiously, the process direction may take a dangerous and often costly route culminating in heavy losses to the company. Unfortunately for the affected mills, the inherent weakness of its process control system often goes unnoticed basically due to low importance being given to process control activities. Process control should therefore not be envisaged as a waste of time by millers, as its implication on productivity far outweighs the cost of establishing and operating a process control unit in a mill.

Under the National Key Economic Area (NKEA), one of the Entry Point Projects (EPP) is to raise the mill oil extraction rate (OER). In order to implement this effectively, the accuracy of the laboratory analysis of the oil lost in empty fruit bunches (EFB), mesocarp fibre and sludge is extremely important. Among these, probably the highest oil loss...
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1. Plant modifications done in your mill that resulted in improvements in milling operation or maintenance.

2. Innovations done in your mill that produced improvements in the operation of the mill and that you are willing to share them with others.

3. Any special work done in your mill that directly resulted in improvements in OER and product quality.

Please submit your article to us and we shall be pleased to publish them in *Palm Oil Engineering Bulletin*. Feel proud to have your articles published in this Bulletin that is circulated throughout the industry and MPOB offices worldwide.

The EFB sampler picks up one bunch from every train of 300 EFB moving slowly along the conveyor. At the end of the day or the next day the samples are quartered a few times, until the sample size is brought down to a manageable size of a mere 50 g to extract the oil in the sample. A better method is the full solvent extraction of the oil from the whole bunch but this is not at all practical, as it tends to be costly and time-consuming.

Perhaps the industry should look into the possibility of using a near infrared (NIR) analyser or similar devices that could continuously scan the moving EFB to capture data. The data can then be converted to give the actual oil content in EFB. This project may be undertaken by any research-minded miller. If successful, the system could be patented. The oil lost in EFB has to be measured accurately in order to modify the milling logistics, so that it can pave the way for bringing down oil loss.

In spite of exponential growth of the palm oil industry worldwide no reasonably accurate method of quantifying the oil lost in EFB has been devised to date. The main issue is the undependable sampling procedure, which can only be described as ludicrous.

The analytical results of oil lost in EFB with reasonable level of accuracy using the prevailing quartering system of sampling is highly questionable. Even this analysis is seldom carried out by some of the private mills. Some established plantation-based mills conduct this test once or twice a year and use these analytical results for all EFB oil loss calculations, while some others assign a zero value for this. The oil lost in EFB is closely related to the percentage of overripe bunches in the FFB consignment, as well as the overfeeding of the threshing machine or its feed conveyors.

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## MPOB TRAINING PROGRAMME SCHEDULE 2012

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## MPOB CONFERENCES/SEMINARS 2012

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**For enquiry or further information, please contact:**

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All information are correct as at press time.
Innovation Potentials in Palm Oil Mill Design

N Ravi Menon*

INTRODUCTION

Horizontal sterilisers are in dire need for improvement. There is great potential for university students to explore the field of sterilisation. It has been found that the sterilisation process practiced by the industry is not founded on sound process technology. There is ample room therefore for improvement not only in the field of sterilisation, but in many other areas of processing as well. In this article, we would focus on sterilisation, the least understood process operation.

The weakness of the sterilisation process stems from its inefficient de-aeration system. Millers have tried single peak, three peaks and multiple peak sterilisation but none of these made any spectacular impact on sterilisation efficiency as such. To begin with, even a thermometer is conspicuously absent in most sterilisers, as without it, the millers will not know the impact of the operation of Dalton’s law of partial pressures on the temperature of steam/air mixture within the steriliser.

Some 30 years ago the millers were very enthusiastic in improving sterilisation efficiency. Various methods of sterilisation regimes were tried out to improve de-aeration, so that the percentage of unstripped bunches remained within limits. Now, bunch crushing and double stripping operations are widely accepted by the industry, as the norm for addressing the consequences of poor stripping efficiency, which served only to effectively camouflage the cause of poor stripping performance.

The problem lies in the lack of understanding of one of the fundamental principles of thermodynamics. Crushing the partially stripped bunches, followed by second stripping, does not remove the original problem of inefficient sterilisation. The mill engineers are encouraged to probe into this matter, so that their attention is focused on the actual cause of the problem. Let us take a close look at the inefficient stripping problem and find out whether it can be solved at the source rather than at the consequence.

At present, the mill process depends solely on the sterilisation efficiency based on the percentage of fruits still remaining in the bunch after the stripping operation is completed. As sterilisation efficiency is a function of the temperature within the steriliser, we should not wait for the actual results of the stripping operation to find out that the stripping had been unsatisfactory, when it is too late. It is more logical to just monitor the thermometer reading and become fully aware that the sterilisation
had indeed been inadequate in real time, even before opening the steriliser door.

The normal sterilisation steam pressure is 3 barg that should have a saturation temperature of 143.6°C. This is indeed a good temperature for sterilisation. This can occur only if the whole steriliser chamber is filled up with steam. What we really have here is a mixture of air and steam. One fundamental mistake in the steriliser instrumentation is that in almost all our mills the thermometer is missing and it would probably not cost more than RM 50. A thermometer can readily tell the engineer, the volume of residual air that still remains in the steriliser after completing the de-aeration operation. It can tell whether the sterilisation had been effective or not.

Everything that is happening within the steriliser in terms of heat transfer to the FFB is reflected by the temperature displayed by the thermometer. Millers may try single peak, triple peak or multiple peak but the efficiency of the impending stripping operation can be predicted by the temperature within the steriliser. We do not have to wait for the actual stripping results.

If throughout the sterilisation time the temperature within the steriliser never exceeded 120°C it can be easily predicted that the sterilisation will be poor. If on the other hand, the temperature remain steady at 130°C or above, the efficiency of sterilisation would undoubtedly be good.

Measuring the temperature is only one part. It will just tell us the sterilisation efficiency that can be expected from the prevailing temperature within the steriliser. It does not tell us how we must address the issues in order to improve the sterilisation efficiency. There is only one parameter that has to be made right, and that is the residual air within the steriliser and it is strongly linked to the temperature.

For this to happen we have to maximise de-aeration. This is not easy to carry out due to many constraints. One obstacle is the high volume of air trapped within the steriliser. No matter how many peaks we set in our sterilisation regime, it is still not possible to realise complete evacuation of air in the steriliser. Let us discuss a popular hypothesis postulated by some in the milling industry. When bunches are heated, the air trapped within bunches will be continuously released. The incoming steam may not be able to push out all the air as they may form pockets encapsulated by steam with no escape route for it during de-aeration. The initial steam flow into the steriliser chamber could be highly turbulent due to high steam velocity followed later by laminar flow when the velocity drops due to low pressure differential between the incoming steam pressure and the steriliser chamber pressure. During the turbulent flow regime, it is possible for the air to form pockets and to remain as pockets without discharging until the steam capsule is dissipated by condensation that may take place at a later stage when sterilisation is nearly completed. As the air pockets are poor conductors of heat, and they are dominant during the early stages of sterilisation within the steriliser, the heat transfer between the steam and bunches can be expected to be poor.

Generally, the mills maintain the last peak for about 30 min with the de-aeration peaks being slotted at the beginning of the cycle. Now assume we start with a 5 min first peak to get rid of most of the air. This can be followed by a second full peak of 20 min pressure cooking, a third peak of 5 min intermediate de-aeration, an additional 20 min full peak pressure cooking and culminate with a 5 min blow off giving a total sterilisation time of 65 min. We are not sure whether this would give better results or not but it does provide for a good air release after bunches are properly heated. The mill engineers are encouraged to carry out different variations of this to arrive at the ideal system. Many innovations of this nature based on basic engineering principles have not been carried out.
CONTINUOUS BLEEDING

Continuous bleeding of condensate was the norm in the early days of the industry but the new engineers or mill designers seem to have overlooked its importance and decided to ignore it as something useless! The continuous release of condensate as well as the air that is continuously released from bunches could effectively nullify the relatively low steam temperature corresponding to the low partial pressure of steam within the steriliser. Some sacrifice of steam is imminent when the condensate bypass is kept open throughout the sterilisation cycle. Probably, a further study is still necessary to ensure the efficient separation and expulsion of air from the condensate pipe. Air bottles fitted with spring loaded relief valves installed on the condensate bypass line can effectively release the air from the air bottle when the air pressure builds up (Figure 1). Other methods also may be available in the market for air release.

Steam Ejectors

These are effective but need high pressure steam for rapid air ejection. If mills have excess steam it is worthwhile to try this to partially evacuate the air prior to the admission of steam. In this case, care must be taken to prevent the collapse of the steriliser shell caused by excessive evacuation of air. A protective system must be incorporated to break the vacuum when it reaches a pre-set value.

Vacuum Pumps

This is a slow process for producing vacuum especially in big vessels like sterilisers. Steam ejectors generate vacuum at a faster rate than vacuum pumps and as such this is not recommended as a suitable system.

Steam Admission Points

This can play an important role in de-aeration process. The current design of air release through the exhaust pipe as practiced by many mills does not appear to be an efficient system for de-aeration. As the air is heavier than steam it will tend to stay at the bottom while the lighter steam will remain at the higher plane. What will happen when steam is admitted in a steriliser containing full of air? When steam is admitted into the steriliser the steam pressure will build up to form the first peak, during which time the exhaust and condensate valves will be generally closed. As the steam gets into contact with the cold air some steam will condense and the enthalpy of condensation of steam (latent heat) will be transferred to the air, thus raising its temperature. The quantity of steam condensed will continuously be replaced by the incoming steam. The pressure indicated on the pressure gauge now will be the sum of the partial pressure of air at the elevated temperature (not at the atmospheric temperature any more) plus the partial pressure of steam.

Figure 1. Steriliser with air bottle fitted with relief valve on condensate bypass line.
Now let us consider what happens to the air immediately surrounding the bunches. As the bunches are encapsulated by a thick layer of air and is held firmly by the live layer of steam the air cannot escape is unable to form the pockets. If it cannot, then during the blow-off operation, most probably, only the steam hovering above the cages will be blown out and not necessarily the air. When eventually the steam pressure is reduced to zero then there is good chance for the air to be evacuated. But in most mills the pressure is kept at half the initial value. There is another area where some modifications can be made to avoid encapsulation of air. The steam can be admitted at the side.

**A SENSIBLE APPROACH FOR ACCOMPLISHING GOOD DE-AERATION**

As air is lighter than steam and the steam pressure will most certainly press down the air, the possibility of air finding a way to pass through the only escape route through the steam, is indeed a mystery. It would make sense if the blow off pipe is located at the bottom, the only problem to this being the large volume of condensate that will accumulate at the bottom of the steriliser during the initial stage of heating.

This tendency for condensate accumulation can be addressed by keeping the condensate valve open during the initial 5 min of sterilisation followed by an intense pressure build-up and de-aeration of say 15 min through large blow-off pipes located at the bottom say 0.5 m above the condensate outlet so that large volume of air can be released in a relatively short time and at the same time avoid the blow out of condensate. The air that is released could pass through a cyclone to reduce its kinetic energy before discharging it into the atmosphere, so that blow off operation does not contribute towards excessive noise level. This is shown in Figure 2.

The above suggestion in no way rules out the possibility of unexpected practical obstacles that could render the proposed system to remain only as a hypothesis. The readers are kindly requested to participate in a dynamic discussion through the Palm Oil Engineering Bulletin on how to improve our milling techniques. We know that some of the engineers in the mills have good ideas but find it difficult to implement it or express it due to the lack of authority to do so. But you can always pool your resources and express it through the Palm Oil Engineering Bulletin. All suggestions are welcome.

*Figure 2. Steriliser fitted with air release header and cyclone.*
WARNING NOTICE

Malaysia Patent No: MY 137253-A
Recovering Oil From Palm Mesocarp Fibre

THE TRADE AND PUBLIC are hereby informed EONCHEM TECHNOLOGY SDN. BHD. of PLO 525, Jalan Keluli 9, Pasir Gudang Industrial Estate, 81700 Pasir Gudang, Johor, Malaysia is the owner of Malaysian Patent No. MY- 137253 -A in respect of recovering oil from palm mesocarp fibres.

The Patent claims a process and assembly of apparatus to extract remaining oil from mesocarp fibres of oil palm after initial extraction of oil. Flow chart of the process is shown below:

NOTICE is hereby given that, any person who, or firm or company which imports, exports, manufactures, offers for sale, sells or uses the process and/or the assembly of apparatus as claimed in the MY-137253-A Patent which does not originate from EONCHEM TECHNOLOGY SDN. BHD. would be committing an act of infringement and legal proceedings will be taken against such persons, or firms or companies.

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(Registered Patent Agent for EONCHEM TECHNOLOGY SDN. BHD.)
The Present Status and Potentials of Biogas Production and Utilisation for Palm Oil Mills-based Residues

Tong, S L * and Lee, A L *

ABSTRACT

The rapid growth of biogas plants in Malaysian palm oil mills in recent times can be attributed to the keen interest of the industry to reduce the greenhouse gas (GHG) emissions from palm oil production, coupled with the potential benefits which can be realised by capturing and utilising the large quantities of biogas to produce renewable energy. During the initial development in the last five to six years, we have observed the applications of the various anaerobic digester technologies for biogas recovery mainly from palm oil mill effluent (POME) treatment systems, where to date, close to 10% of the palm oil mills have installed some forms of biogas-capture systems. Exponential growth is expected with this trend extending to cover all of the approximately 1000 mills in the ASEAN region. With the expansion of the biogas industry, the potential of the next generation biogas production using alternate sources can be expected. Palm oil mill residues, like POME slurry, solid palm waste materials (empty fruit bunches and oil palm by-products) can become alternative or supplementary feedstock materials, to give much higher biogas yields than that from POME. Accompanying this development, various methods of utilisation of the biogas generated has been realised, but it was limited mainly to on-site applications in accordance with site specific factors. These include applications for thermal energy recovery in the different types of boiler systems and for power generation via gas engines for on-site use or connection to the grid. However, the challenges still remained for development of off-site utilisation for the biogas recovered. Prospective applications after upgrading of the biogas (biogas refining), such as compressed natural gas (CNG) equivalent (transport fuel), feeding to natural gas (NG) pipeline and bottling, and transportation for offsite industrial use, also can be foreseen.

INTRODUCTION

The capture of biogas from palm oil mill effluent (POME) treatment system using a closed-tank anaerobic digester system by the palm oil industry has been reported since the early 1980s (Quah and Gilles, 1981; 1984). However, due to the high cost of construction and the lack of economically attractive utilisation of the biogas recovered,
there has been, until very recently, only one successful closed-tank anaerobic digester system built in nearly 400 palm oil mills in Malaysia (Chua and Gian, 1986; Tong and Bakar, 2005). The system which has been in continuous operation for over 27 years to date is the one at Keck Seng Palm Oil Mill in Masai, Johor, which is located next to a palm oil refinery complex, with high demand for energy supplies.

However, a rapid growth of new POME biogas plants has been observed over the last five to six years. The main motivating factor for this development is the desire to reduce the greenhouse gas (GHG) emissions which lead to a reduction in the carbon footprints during palm oil production. The other benefit is capturing of the large quantities of biogas for utilisation as a form of clean renewable energy (RE).

This article reviews the methane production potentials, technology and the utilisation development extending from the present generation of POME biogas plants to the development of the large scale next generation biogas production, making use of other abundant palm oil mill biomass residues or by-products as feedstock materials.

**METHANE PRODUCTION POTENTIALS OF PALM OIL MILL BIOMASS RESIDUES**

Palm oil represents the largest proportion of the world’s vegetable oil production in recent decades. The combined world palm oil production of 45.06 million tonnes and palm kernel oil of 5.21 million tonnes in 2009 accounts for 36.02% of the total world vegetable oil production at 139.59 million tonnes. The combined total for Malaysia and Indonesia at 18.50 and 20.75 million tonnes, respectively, amounts to 87% of the total world palm oil production. On this basis, the scale of biomass residues availability from the oil palm plantation and palm oil industrial sector has been recognised as an important resource of biomass feedstock for RE generation.

Table 1 adapted from Ma et al. (1999) summarises the energy potentials of the various biomass residues from the oil palm sector in Malaysia for 2009. Biogas production via the biochemical processes is one of the major means of tapping the energy potentials from these biomass feedstocks.

**Methane Production from Palm Oil Mill Effluent**

Although methane production potentials, as shown in Table 1 are much higher from the solid biomass residue materials, to date only the tapping of methane generation from POME has taken place since the technology has been well-developed and readily available. The gross energy potential for 2009 is estimated as 33,900 TJ yr\(^{-1}\) based on the 2009 crude palm oil production of 17.57 million tonnes. Table 2 shows the estimated quantities of potential methane recoverable for both Malaysia and Indonesia at 675,000 and 803,000 t yr\(^{-1}\), respectively in terms of weight, and 946 x 10\(^{6}\) and 1126 x 10\(^{6}\) Nm\(^{3}\) yr\(^{-1}\), respectively in terms of volume. Through the capture and destruction of the POME methane, emission reduction potentials of 14.2 x 10\(^{6}\) CO\(_2\)-e yr\(^{-1}\) and 16.9 x 10\(^{6}\) CO\(_2\)-e yr\(^{-1}\) have been estimated for the two countries, respectively.

These projected methane production potential figures have been proven to be achievable based on the actual historical biogas production data reported for a number of POME biogas plants installed. Table 3 shows the theoretical methane/biogas yields from anaerobic digestion of POME. For optimally designed closed-tank completely mixed anaerobic digester system, assuming a chemical oxygen demand (COD) input concentration at 54,000 mg litres\(^{-1}\) and COD removal rate of 80%, biogas production of 28 m\(^{3}\)biogas m\(^{3}\) POME \((60\% \text{ CH}_4)\) has been achieved consistently.
### TABLE 1. ENERGY POTENTIAL OF BIOMASS RESIDUES FROM THE OIL PALM SECTOR IN MALAYSIA (2009)

<table>
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<tr>
<th>Biomass residues</th>
<th>Quantity t t(^{-1}) FFB</th>
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<th>total t yr(^{-1})</th>
<th>Energy potential TJ yr(^{-1})</th>
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<tr>
<td>Empty fruit bunches (EFB)</td>
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<td>20.20</td>
<td>128 000 (biomass)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[126 100 (biogas)]</td>
</tr>
<tr>
<td>Mesocarp fibres</td>
<td>0.12</td>
<td>-</td>
<td>10.51</td>
<td>112 000</td>
</tr>
<tr>
<td>Palm kernel shells</td>
<td>0.07</td>
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<td>6.15</td>
<td>93 000</td>
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<tr>
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<td>2.515</td>
<td>12.15</td>
<td>221 000</td>
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<tr>
<td>Fronds</td>
<td>-</td>
<td>10.88</td>
<td>52.55</td>
<td>1 041 000</td>
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<tr>
<td>Palm oil mill effluent</td>
<td>0.67</td>
<td>-</td>
<td>58.79</td>
<td>33 900 (biogas)</td>
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</table>

Note: FFB – fresh fruit bunches.

### TABLE 2. GROSS METHANE RECOVERABLE FROM PALM OIL MILL EFFLUENT (POME) FOR MALAYSIA AND INDONESIA (2009) - FIRST GENERATION BIOGAS PLANTS

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<td>Annual crude palm oil (CPO) production</td>
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<td>62.80</td>
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<td>Total COD loading</td>
<td>t yr(^{-1})</td>
<td>2 699 000</td>
<td>3 211 000</td>
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<tr>
<td>Potential methane recoverable*</td>
<td>t yr(^{-1})</td>
<td>675 000</td>
<td>803 000</td>
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<tr>
<td></td>
<td>10(^{6}) Nm(^{3}) yr(^{-1})</td>
<td>946</td>
<td>1 126</td>
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<tr>
<td>Potential GHG emission reductions</td>
<td>10(^{6}) CO(_{2}) e yr(^{-1})</td>
<td>14.2</td>
<td>16.90</td>
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</table>

Note: COD – chemical oxygen demand.
GHG – greenhouse gas.
* Based on IPCC Guidelines: 0.25 kg CH\(_{4}\)/kg COD.

Biogas production rate in practice, on the basis of a medium size palm oil mill, is shown in Table 4. Methane recoverable is approximately 2657 t yr\(^{-1}\), with an energy rate of 133.4 TJ yr\(^{-1}\) or 3 795 781 litres yr\(^{-1}\) of diesel equivalent.

**Methane Production Potentials of Slurry and Solid Biomass Residues**

Methane production potentials of certain slurry and solid biomass residues from palm oil mills which are available in abundance such as the slurry from oil extraction decanter systems and empty fruit bunches (EFB) have been tested. Table 5 presents a set of typical findings. The methane yield for decanter slurry of 67 m\(^{3}\) t\(^{-1}\) fresh slurry (fs) and an energy yield of 665 kWh t\(^{-1}\) fs are about 2.4 times higher than that of POME, whereas for EFB, the methane yield of 174 m\(^{3}\) t\(^{-1}\) fs and an energy yield of 1728 kWh t\(^{-1}\) fs are approximately 6.2 times that of the liquid effluent.

**TECHNOLOGY DEVELOPMENT FOR BIOGAS PRODUCTION FROM PALM OIL MILL BIOMASS RESIDUES**

Biogas technologies can be considered in the following three categories, in accordance with the different characteristics of the oil palm biomass residues.
Anaerobic digestion of POME

- Organic substance: 1% to 6% total solids.
- Technology: complete-mixed stirred-tank reactor (CSTR) for anaerobic digestion – first generation biogas plant.

Anaerobic digestion of slurry and by-products

- Organic substance: 8% to 15% total solids.

---

**TABLE 3. THEORETICAL METHANE/BIOGAS YIELDS FROM PALM OIL MILL EFFLUENT (POME) ANAEROBIC DIGESTION**

<table>
<thead>
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<th>Theoretical methane yield</th>
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<tr>
<td>Nm³CH₄ kg⁻¹ COD</td>
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<td>kg CH₄ kg⁻¹ COD</td>
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**POME organic matter conc. (COD)**

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<th>COD, kg m⁻³ POME</th>
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<td>COD removal rate</td>
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**Methane production:**

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<th>kg CH₄ m⁻³ POME</th>
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<tr>
<td>Nm³CH₄ m⁻³ POME (273 K)</td>
<td>15.1</td>
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**Methane/biogas volume yield (308 K)**

<table>
<thead>
<tr>
<th>m³CH₄ m⁻³ POME (308 K)</th>
<th>17.1</th>
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<tr>
<td>m³ biogas m⁻³ POME (60% CH₄)</td>
<td>28.4</td>
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</table>

Note: COD – chemical oxygen demand.

---

**TABLE 4. PALM OIL MILL EFFLUENT (POME) BIOGAS/METHANE OUTPUT FOR A 60 t FRESH FRUIT BUNCHES (FFB) PALM OIL MILL**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Quantity</th>
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<tr>
<td>FFB (t hr⁻¹)</td>
<td>60</td>
</tr>
<tr>
<td>FFB (t yr⁻¹)</td>
<td>360 000</td>
</tr>
<tr>
<td>POME (m³ yr⁻¹)</td>
<td>216 000</td>
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<tr>
<td>Total COD load (t yr⁻¹)</td>
<td>10 800</td>
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<tr>
<td>CH₄ produced (t yr⁻¹)</td>
<td>2 657</td>
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<tr>
<td>CH₄ (273 K) (Nm³ yr⁻¹)</td>
<td>3 726 227</td>
</tr>
<tr>
<td>Biogas (308 K) (m³ yr⁻¹)</td>
<td>6 726 318</td>
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<tr>
<td>Energy rate (TJ yr⁻¹)</td>
<td>133.4</td>
</tr>
<tr>
<td>Diesel equiv. (litres yr⁻¹)</td>
<td>3 795 781</td>
</tr>
<tr>
<td>Estimated CER, t CO₂-e yr⁻¹</td>
<td>36 000</td>
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</table>

Note: COD – chemical oxygen demand.
Anaerobic digestion of solid biomass

- Organic substance: 25% to 40% total solids.
- Technology: solid anaerobic digester – third generation biogas plant.

The initial development of the first generation biogas plants which evolved rapidly since 2006 mainly focused on the anaerobic digestion of POME, where technology was more readily adaptable. Second and third generation biogas plants are expected to be developed, as the industry is expected to grow with increasing numbers of POME biogas plant projects being implemented and supported by higher R&D inputs.

The transition from the first to the future generations of biogas plant development hinges on the differences in the requirements of oil palm biomass residue feedstocks in the optimisation of the biochemical processes of the anaerobic digestion. Figure 1 briefly illustrates the main rate of controlling steps and biomass utilisation in the anaerobic digestion processes.

The different requirements, for pre-treatment, due to the different characteristics of the three groups of biomass feedstock, are outlined below:

POME (first generation biogas plants)

- Well homogenised and well dispersed.
- High in dissolved substrate, and low in lignocellulose fibres.
- Minimal pre-treatment required in CSTR mesophilic anaerobic digestion.

Decanter slurry, by-products and residues (second generation biogas plants)

- Moderate in dissolved substrate, and moderate in lignocellulose fibres.
- Pre-treatment to breakdown lignocellulose would improve methane yield.

Solid biomass - EFB, tree trunks (third generation biogas plants)

- High in lignocellulose fibres.
- Pre-treatment to breakdown lignocellulose required to maximise biomass utilisation - development of enzymatic hydrolysis.
Anaerobic Digester Technology for Palm Oil Mill Effluent Biogas Capture

Of the closed-tank anaerobic digester technology for POME biogas capture, Quah and Gilles (1981) and Chua and Gian (1986), have reported on Keck Seng’s closed tank anaerobic digester system. It is based on the continuous-flow stirred-tank reactor using contact process (CSTR-Contact) principle. It was the earliest closed-tank technology offered by Novaviro Technology Sdn Bhd to meet the demand of the industry (Tong and Bakar, 2005; Tong et al., 2008). The KS-CSTR anaerobic digester technology which operates with the provision of a dual function complete-mixed system in the mesophilic range. It had an optimum hydraulic retention time in the range of 17 - 18 days, and it also offered the efficient POME biogas capture, approaching the theoretical methane yield level. The first KS-CSTR system which was commissioned in 1984 has been in continuous operations
for 27 years, with consistent records of biogas output. Photos of this system and a few recently installed KS-CSTR biogas plants are shown in Figure 2.

A few alternative technologies have emerged since 2006/2007 and most of these were reported and published in the project design documents (PDD) under the Kyoto Protocol Clean Development Mechanism (CDM), and in forums promoting GHG emission reductions in POME treatment. These technologies include: (i) flow-through tank digester system; (ii) thermophilic anaerobic digester tank system; and (iii) membrane-covered anaerobic lagoon system. Table 6 shows that a total of 66 projects from Malaysia have been submitted to the UNFCCC CDM Executive Board for validation to date. Among these, a total of 34 projects, 16 of closed-tank systems and 18 of membrane-covered lagoons, have been registered.

Biogas production figures based on the historical data for projects which have been registered are shown in Table 7.

### TABLE 6. CLEAN DEVELOPMENT MECHANISM (CDM)-DRIVEN PROJECT DEVELOPMENT - METHANE RECOVERY AND UTILISATION CDM PROJECTS FROM MALAYSIA

<table>
<thead>
<tr>
<th>Status*</th>
<th>Closed tank system</th>
<th>Membrane-covered system</th>
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<tr>
<td>Total No. of projects submitted for validation</td>
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<tr>
<td>Total No. of projects registered</td>
<td>16</td>
<td>18</td>
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<td>Total No. of projects requesting CERs issuance</td>
<td>Submitted monitoring report</td>
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<td>CER issued</td>
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Note: *As of June 2011. CER – carbon emission reduction.

### TABLE 7. PALM OIL MILL EFFLUENT (POME) BIOGAS YIELD REPORTED IN PUBLISHED CDM PROJECT MONITORING REPORTS

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Technology</th>
<th>Monitoring period</th>
<th>COD input kg m⁻³</th>
<th>m³ biogas/m³ POME</th>
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<tr>
<td>0867</td>
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<td>25.88</td>
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<td>148.89</td>
<td>36.52</td>
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Note: CSTR – complete-mixed stirred-tank reactor.
been implemented in the last few years are available in the monitoring reports published in the UNFCCC CDM website. Table 7 presents a summary of the biogas yield extracted from these reports. The data indicated that the CSTR systems had been able to achieve the expected biogas yield corresponding to the POME feeding rate.

**Anaerobic Digester Technology for Slurry and Empty Fruit Bunches**

For palm oil mill residue in the slurry form, a suitable anaerobic digester design for second generation biogas plant, based on a plug-flow digester design, is illustrated in Figure 3.

The characteristics of the solid anaerobic digester system are briefly outlined in Figure 4.

- digester loading: 10 to 20 kg COD m\(^{-3}\) reactor per day;
- temperature range: thermophilic: 48°C to 57°C (or mesophilic: 35°C to 40°C) reactor per day;
- retention time in the digester: 15 to 30 days;
- biogas production: 100 to 200 Nm\(^3\) of biogas per tonne of waste; and
- electricity production: 220 to 440 kWhr per tonne of waste production.

**RECENT PROGRESS IN BIOGAS UTILISATION**

Biogas with 60% to 70% CH\(_4\) concentration can be utilised in both on-site and off-site applications (after purification):

An on-site application includes the following:

For direct fuel replacement (Figure 5):

- high pressure boiler;
- package boiler
- vapour absorption chiller;
- hot air burner; and
- co-firing in biomass boiler.
Use after desulphurisation:

- for gas engines (35%-43% efficiency)
  – for local use or grid connection;
- gas turbine (25%) efficiency; and
- hydrogen purification.

Off-site application (after purification or upgrading) (Figures 6 and 7):

- vehicle fuel – CNG equivalent;
- injection to local gas grid or NG grid;
- bottling for distribution; and
- liquefaction for distribution.

For off-site applications including: vehicle fuel – as CNG equivalent, injection to local gas grid or NG grid, bottling for distribution, and liquefaction for distribution, the following technologies, such as chemical absorption, water scrubber, cryogenic, pressure swing adsorption and membrane process are shown in Figure 8. The most appropriate for adaptation appears to be the water scrubber technology, for which the operating and maintenance costs may be significantly lower than others.

Examples of application of biogas on-site after purification (H₂S scrubbing) are shown in Figure 7.

CONCLUSION

The first generation POME biogas projects provide the industry with the ground work to develop the full potential of the palm oil mill residues for bio-methane production.

The development of the second and third generation biogas plants which utilise palm

Figure 5. Some examples of direct fuels displacement utilisation for on-site applications.

Figure 6. Utilisation of biogas/methane in biomass-biogas co-firing boiler.
6x500 kW gas engines installed in Sabah

Figure 7. Biogas on-site application after purification.

Figure 8. Off-site application.

Oil mill slurry and solid biomass residues, still require further R&D, with respect to pre-treatment, including enzymatic hydrolysis, to ensure more effective utilisation of the total biomass residues.

In biogas utilisation, power generation for on-site applications and grid connection are rapidly developing and upgrading of technologies will enable transportability and off-site utilisation of the product gas.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the valuable information and support from the management of Keck Seng (Malaysia) Berhad, and all colleagues from Oiltek Nova Bioenergy Sdn Bhd.
REFERENCES


Achieving a BOD below 20 mg litre\(^{-1}\) for POME: Is it a Myth or a Reality?

Ronnie C W Tan*

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**INTRODUCTION**

There are a number of effluent treatment systems available now in the market claiming to give excellent results. This could be a valid claim because in most cases it would have performed satisfactorily with other types of effluents. But the problem often overlooked is the dissimilar characteristics of different types of effluents. Each treatment system has to be separately evolved and custom made to be effective. It could be a costly mistake if we blindly adopt a system with a proven track record of effluent treatment when dealing with another industry. One of the critical characteristics of palm oil mill effluent is its extraordinarily high biochemical oxygen demand (BOD), that can be as high as 30 000 mg litre\(^{-1}\). Currently, most mills are struggling to keep it below the existing Department of Environment (DOE) limit of 100 mg litres\(^{-1}\). Soon this will have to be lowered to 20 mg litres\(^{-1}\) to keep pace with the rest of the world.

Some of the existing systems that had been tried out in palm oil industry are as follows: (i) DAF System, (ii) Activated Biological Sludge + Aeration System, (iii) Aerated Lagoon System, (iv) Aerated, Clarification Setting Tanks System, and (v) Biological Media System. So far NONE of the proponents of these systems are willing to guarantee a BOD of less than 20 ppm consistently. It is no use if it irregularly gives good results.

Recently, a new method called the biological chemical mechanical and membrane (BCMM) technology has been tried out under R&D in MPOB Palm Oil Mill Technology Centre (August 2010 – February 2011) and in FELDA’s Kilang Sawit Neram (January – August 2012), that seemed to deliver consistent results under the normal mill operating conditions.

BCMM is a tertiary effluent polishing plant developed by Concept Engineering and it consists of (Figures 1, 2 and 3): (i) biological method, (ii) aeration chemical method, (iii) flocculation/polymer, (iv) mechanical method, (v) lamella separator, (vi) continuous sand filter, (vii) membrane method, and (viii) UF

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E-mail: sales@concept-engineering.net
**Feature Article**

**Waste Water Treatment (POME) (BCMM System) Malaysia**

- **Final Algae Pond**
  - pH 7-8, Oil & Grease 60 ppm
  - BOD (Max) 400 ppm, COD 600 ppm
  - Total Solid <5000 ppm Max

- **Aerobic Stage**
  - 50-100 ppm

- **Polishing Phase**
  - LAMELLA
  - SLUDGE (Dewatering)
  - CHEMICALS

- **Final Discharge**
  - BOD < 20 ppm, COD < 300 ppm
  - SS < 20 ppm, AN < 250 ppm
  - TN < 200 ppm, TDS < 4,000 ppm
  - PH 7-8

- **WATER AFTER RO CAN BE REUSED FOR BOILER.**

**Figure 1.** The BCMM plant at FELDA K S Neram.

**Figure 2.** Stages of waste water treatment (BCMM) system.
Figure 3. Stages of waste water treatment (BCMM) system.
Figure 4.
Figure 5.
Figure 6.
Figure 7.
Figure 8. FELDA K S Neram tertiary treatment plant layout.

see page 41
### TEST RESULTS FROM PILOT PLANT LAF-FELDA NERAM

5 m³ hr⁻¹ R&D Polishing Plant (Neram mill FELDA)

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Note: All units in mg litre⁻¹ except pH.
- BOD - biological oxygen demand.
- COD - chemical oxygen demand.
- SS - suspended solids.
- TS - total solids.
- AN - ammoniac nitrogen.
- TN - total nitrogen.
technology. This has the capacity for reducing and maintaining BOD below 20 ppm before effluent is discharged or to be reused for cleaning purpose.

In our R&D studies, Concept Engineering focused on the following: stability and reliability of this technology in maintaining and achieving BOD <20 ppm consistently, in compliance with the DOE Standard for palm oil mill effluent (POME) discharge. The system also efficiently removes the suspended solids to comply with the DOE Standard of SS below 400 mg litre\(^{-1}\), ammoniac nitrogen below 150 mg litre\(^{-1}\), total nitrogen below 200 mg litre\(^{-1}\) and also improves the clarity of the discharged water as shown in figures. Consideration was also given to operational and maintenance cost as well as the possibility of whether the water can be recycled for boiler use without further treatment, per cost m\(^3\) of POME.

**CONCLUSION**

From the trials conducted we were able to draw the following conclusions:

- the system was very stable in consistently achieving BOD less than 20 mg litre\(^{-1}\) at the point of discharge complying with the expected DOE limit of less than 20 mg litre\(^{-1}\);
- the suspended solids (SS) measured less than 30 mg litre\(^{-1}\) after ultra-filtration at discharge point complying with the limit of less than 400 mg litre\(^{-1}\);
- ammoniac nitrogen (AN) concentration of less than 80 mg litre\(^{-1}\) and total nitrogen (TN) of less than 119 mg litre\(^{-1}\) also were well below the DOE limit of 150 mg litre\(^{-1}\) and 200 mg litre\(^{-1}\) respectively;
- total dissolved solids did not change much. It remained high at more than 3000 mg litre\(^{-1}\) indicating that it cannot be used as a make-up water for the boilers without further treatment.
- the pH remained lightly alkaline between 7 to 9; and
- the system was easy to operate. The chemical cost was about 20 sen m\(^3\).
### STANDARD MILLING PRODUCT LOSSES

<table>
<thead>
<tr>
<th>Product</th>
<th>Oil loss to dry matter</th>
<th>Oil loss to wet matter</th>
<th>Moist</th>
<th>Non-oily solids</th>
<th>Free fatty acid</th>
<th>Dirt</th>
<th>DOBI</th>
<th>Fibre/ nut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Press fibre (%)</td>
<td>7.00 - 9.00</td>
<td>4.00 - 6.00</td>
<td>35.00 - 45.00</td>
<td>45.00 - 50.00</td>
<td>-</td>
<td>-</td>
<td>1.00 - 1.50</td>
<td></td>
</tr>
<tr>
<td>ST. condensate (%)</td>
<td>12.00 - 15.00</td>
<td>5.00 - 7.00</td>
<td>90.00 - 95.00</td>
<td>4.00 - 5.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Decanter cake (%)</td>
<td>12.00 - 15.00</td>
<td>4.00 - 6.00</td>
<td>5.00 - 6.00</td>
<td>90.00 - 5.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>CPO production oil</td>
<td>-</td>
<td>0.10 - 0.20</td>
<td>-</td>
<td>2.50 - 4.50</td>
<td>0.015 - 0.020</td>
<td>&gt; 2.3</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product</th>
<th>Kernel losses</th>
<th>Whole nut</th>
<th>Broken nut</th>
<th>Whole nut</th>
<th>Broken kernel</th>
<th>Moist</th>
<th>Dirt/ shell</th>
<th>Free fatty acid</th>
<th>Efficiency</th>
<th>Fibre/nut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre cyclone (%)</td>
<td>1.00 - 2.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Low tension dust separator (LTDS) (%)</td>
<td>2.00 - 3.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Wet shell (%)</td>
<td>3.00 - 5.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Nut cracker</td>
<td>-</td>
<td>0.5 - 1.00</td>
<td>1.00 - 1.50</td>
<td>28.00 - 38.00</td>
<td>10.00 - 2.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>97 - 98</td>
<td></td>
</tr>
<tr>
<td>Prod kernel</td>
<td>-</td>
<td>10.00 - 12.00</td>
<td>3.00 - 5.00</td>
<td>2.00 - 3.00</td>
<td>6.00 - 7.00</td>
<td>5.00 - 6.00</td>
<td>-</td>
<td>-</td>
<td>0.50 - 1.00</td>
<td></td>
</tr>
<tr>
<td>Polishing drum</td>
<td>-</td>
<td>-</td>
<td>10.00 - 12.00</td>
<td>3.00 - 5.00</td>
<td>2.00 - 3.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product</th>
<th>Fibre/nut</th>
<th>B. nut/t. nut</th>
<th>Free b. kernel</th>
<th>Cracked nuts</th>
<th>Free shell</th>
<th>Oil in wet fibre</th>
<th>Oil in dry fibre</th>
<th>Moisture in fibre</th>
<th>Shell/kernel ratio</th>
<th>Moisture in kernel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Press cake analysis</td>
<td>1.50</td>
<td>&lt;10.00</td>
<td>&lt;1.00</td>
<td>&lt;10.00</td>
<td>&lt;1.00</td>
<td>&lt;5.00</td>
<td>&lt;8.00</td>
<td>&lt;45.00</td>
<td>1.50</td>
<td>21.00 - 22.00</td>
</tr>
</tbody>
</table>

Note: DOBI - deterioration of bleachability index.  
CPO - crude palm oil.
Due to the increased cost of printing, the advertisement rate is RM 700 per issue for an A4 size page of black and white, whereas the cost for colour is RM 900. One year of complimentary Vendor’s List advertisement for every one page A4-size colour or black & white advertisement. Advertisers are required to submit to us either their own black and white or colour artwork in CD. Cheque should be made payable to the ‘Malaysian Palm Oil Board’. If you have any queries, please contact the following at MPOB.

Tel: 03-87694400  Fax: 03-89262971

Dr. Lim Weng Soon  ext: 4406  •  Ir. N. Ravi Menon  ext: 4467  •  Lim Soo Chin  ext: 4676
E-mail: milleng@mpob.gov.my

Advertising Schedule for MPOB Palm Oil Engineering Bulletin

<table>
<thead>
<tr>
<th>Issue</th>
<th>Quarter</th>
<th>Deadline for Registration</th>
<th>Deadline for Submission of Artwork</th>
</tr>
</thead>
<tbody>
<tr>
<td>106</td>
<td>Jan - Mar 2013</td>
<td>30 Jan 2013</td>
<td>28 Feb 2013</td>
</tr>
<tr>
<td>107</td>
<td>Apr - June 2013</td>
<td>30 Apr 2013</td>
<td>30 May 2013</td>
</tr>
</tbody>
</table>

REPLY-SLIP

Dr. Lim Weng Soon/Ir. N. Ravi Menon
Engineering and Processing Division
Palm Oil Engineering Bulletin
MPOB
6, Persiaran Institusi
Bandar Baru Bangi
43000 Kajang, Selangor

PALM OIL ENGINEERING BULLETIN ADVERTISEMENT – FULL PAGE ADVERTISEMENT

1. We confirm our intention to advertise in the MPOB Palm Oil Engineering Bulletin.

   Company: 

   Address: 

   E-mail: 
   Tel. No.: 
   Fax No.: 
   Contact Person: 
   Issue No.: 

2. The artwork is attached/will be sent on ______________________ for your further action.

3. Please find enclosed *crossed cheque No.: ___________ for RM ______________________ being payment for the advertisement fee.

4. Thank you.

   (Signature and Date)  (Company stamp)

* Made payable to ‘MALAYSIAN PALM OIL BOARD’.
Following a decision by the Editorial Board to further increase the role of Palm Oil Engineering Bulletin to serve the industry better, a new addition called Palm Oil Mill Vendor’s List has been introduced similar to Telekom Yellow Pages to assist mill engineers to know where to source materials or services pertaining to the industry. In order to make this useful, we need the co-operation of the mill engineers/managers to persuade their vendors to advertise in the Vendor’s List for a nominal fee of RM 100/year. If you have any queries, please contact the following at MPOB.

Tel: 03-87694400   Fax: 03-89262971

Ir. Ravi Menon ext. 4467 or e-mail: nravi@mpob.gov.my
Ms. Lim Soo Chin ext. 4676 or e-mail: milleng@mpob.gov.my

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**REPLY SLIP**

Dr. Lim Weng Soon/Ir. N. Ravi Menon
Engineering and Processing Division
Palm Oil Engineering Bulletin Advertisement
MPOB, 6, Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia.

We wish to advertise in the MPOB Palm Oil Engineering Bulletin Vendor’s List

<table>
<thead>
<tr>
<th>Company:</th>
<th>Issue No.:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Person:</td>
<td>H/P:</td>
</tr>
</tbody>
</table>

Address:

E-mail: ___________ Tel: ___________ Fax: ___________

Please find enclosed a crossed cheque No.: ___________

for RM: ________ (Ringgit Malaysia) drawn in favour of MALAYSIAN PALM OIL BOARD

Please select the headings from the list given below (not more than five headings) under which you wish to advertise.

- Air filters/dryers
- Air compressors
- Bearings/belts/bushes
- Biomass/bio-compost/products
- Boiler spares/control/others
- Boiler suppliers
- Bunch crushers
- Castings
- Civil engineering
- Cleaning - general
- Condition monitoring
- Consultancy services/certification
- Control/automation/spares
- Conveyors/chains/elevators/belts
- Diesel eng./services/spares
- Dynamic balancing
- Electric motors/systems
- Expansion joints
- Fabrication works
- Fans
- Filter press/materials
- Fluid control system/couplings
- Gaskets/packing materials/seals
- Gear boxes
- Hardware
- Hydraulic systems/services/spares
- Laboratory analysis
- Laboratory equipment
- Lubricants
- Mill machinery/spares
- Miscellaneous
- Nut crackers
- Oil recovery systems
- Palm kernel oil crushing plant
- Power plant
- Pollution control/safety systems
- Pressure vessels
- Pumps/services
- Purifiers
- Screw press/parts
- Scrubbers
- Sludge separators/decanters
- Steam turbines/generator/spares
- Sterilizer/parts
- Storage silos
- Vacuum pumps
- Valves/seats
- Waste water treatment
- Water treatment
- Weighing machines/spares
- Welding equipments
- Wheel loaders/spares

Signature: ____________________________  
Name: ____________________________  
Date: ____________________________  

Company stamp
(We have enclosed this form to assist you in sending to us any questions or comments)
IT’S COMING AGAIN, the grand Palm Oil Congress with five concurrent Conferences which examines and discusses the many facets of the palm oil industry. The last PIPOC in 2011 was attended by more than 2000 participants from 46 countries. It also boasts of more than 200 exhibition booths.

So make sure you will be one of them in 2013

PIPOC 2013 features 5 concurrent Conferences, namely:
• Agriculture, Biotechnology & Sustainability
• Chemistry, Processing Technology & Bio-Energy
• Food, Lifestyle Chemicals
• Global Economics & Marketing
• Oleo & Specialty Chemicals

(An Evening Forum on current matters will also be held)

You may opt to be:
SPEAKER, POSTER PRESENTER or PARTICIPANT

or your organisation may:
• EXHIBIT your products and/or services
• ADVERTISE in the Souvenir Programme of the Congress
PIPOC 2011 was attended by more than 2000 participants from 46 countries. What better way to keep abreast with the rapid developments and changes in the oil palm industry than to attend PIPOC 2013? This bi-annual Congress provides a platform that showcases the latest advances in the industry. It provides an excellent arena for networking and sharing information.

As a value-added feature, PIPOC 2013 boasts of an exhibition hall with a vast floor space of 2000 m² that would house 200 booths. The new technologies and the information showcased here would be a storehouse of knowledge and help you to increase the productivity and profitability of your business.

Technical On-site Tours
Visiting plantations, oil palm mills, refineries, oleochemical plants and R&D facilities

Golf Tournament
A special golf tournament will be organised for our golf enthusiasts.

...so hope to see you in PIPOC 2013!

Don’t forget to mark your calendar and extend our invitation to your friends and colleagues

<table>
<thead>
<tr>
<th>Congress Registration Fee</th>
<th>RM</th>
<th>EURO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Participants</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Early bird (before 30 June 2013)</td>
<td>2 300</td>
<td>600</td>
</tr>
<tr>
<td>2. Normal (after 30 June 2013)</td>
<td>2 600</td>
<td>676</td>
</tr>
<tr>
<td>3. Poster Presenters and Students</td>
<td>1 300</td>
<td>350</td>
</tr>
<tr>
<td><strong>MPOB Licensees</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 100</td>
<td>-</td>
</tr>
<tr>
<td><strong>Exhibition Fee varies with location</strong></td>
<td>11 000</td>
<td>2 800</td>
</tr>
<tr>
<td></td>
<td>12 000</td>
<td>3 000</td>
</tr>
</tbody>
</table>

organised by:
Malaysian Palm Oil Board (MPOB)
MINISTRY OF PLANTATION INDUSTRIES AND COMMODITIES, MALAYSIA

For more information, please contact • pipoc2013@mpob.gov.my