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PALM OIL MILL EFFLUENT (POME) FROM MALAYSIA PALM OIL MILLS: WASTE OR RESOURCE

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Abstract: During the last century, a great deal of research and development as well as application has been devoted to pollution control advance technologies for treatment and management of both solid and liquid waste generated from palm oil mills. The major reason for such huge efforts is that waste generated from palm oil mills have been declared as one of the major source of environmental pollution. Although palm oil mills generate both solid and liquid wastes, but according to this review, palm oil mill effluent (POME) has been singled out by the operators as the most expensive and difficult waste to manage. This paper aims to present the potentials of POME as a resource that can contribute to world economic and sustainable development. The emergent of the new biotechnological advances and POME treatment technologies like POMETHANE (an anaerobic thermophilic digestion process which maximizes the yield of biogas production) has changed the status of POME from waste to resource. Use of current advance technologies to manage POME by mill operators will not only turn POME to resources, but also means of achieving zero discharge concepts
Keywords: Palm oil mill; Palm oil mill effluent (POME); Waste; Resource; POME treatment Technology.

1. Introduction

Although, palm oil mill effluent (POME) is not the only waste generated during processing of fresh fruit bunch (FFB). But it is the most expensive and difficult waste to manage by mill operators. This is because large volumes in tonnes are generated at a time. The palm oil industry still considers POME treatment a burden rather than as part of the production process, let alone a profit centre (Ma A.N. 1999). For these obvious reasons, raw POME or partially treated POME is still being discharged into nearby rivers or land, as this is the easiest and cheapest method for disposal. However, excessive quantities of untreated POME deplete a water body of its oxygen and suffocate aquatic life. Many small and big rivers have been devastated by such discharge as people living downstream are usually affected.

This was evident in the frustration of Keningau and Murat villagers who repeatedly reported the case of pollution to press to tell the world that palm oil mills are polluting the Ongom,

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Ambual and Punti rivers. Murat villagers complained that oil and dirt pollution from a relatively new mill had crippled a water source for residents in the plains of Pegalan River. Beyond obvious water pollution problems, is the use of both aerobic and anaerobic digestion by palm oil mills in treating POME. Methane, a greenhouse gas, 25 times more potent than carbon dioxide in trapping heat is generated during anaerobic digestion of POME. Palm oil mills are fingered by climate change authorities as being the second largest source of methane generator in Malaysia, (38%), next to landfills (53%). Methane or biogas from palm oil mills is therefore chief contributor to world global warming.

During the last century, a great deal of research and development as well as application has been devoted to new advance POME treatment technologies (PTT). The major reason for such huge efforts is that POME generated from processing of FFB has been declared as one of the major source of environmental pollution. Even with the advent of the new biotechnology advances and PTT like POMETHANE. Palm oil mills are still struggling to meet up with more stringent limits of effluent discharge allowed.

By 1984, law on effluent discharge in Malaysia limits the Biochemical Oxygen Demand (BOD) to 100 parts per million (PPM). However, in environmentally sensitive areas of Sabah and Sarawak like Kinabatangan River, Department of Environment (DOE) Malaysia imposed a more stringent condition of 20ppm since 2006. For new mills, a 20ppm BOD requirement coupled with land irrigation has been imposed in Sabah. In very sensitive areas, the DOE has even imposed a zero discharge requirement.

Over the last decades, the management of POME has evolved from treatment of the "POME for disposal" to beneficial, utilisation of either treated POME and or its by-products (Ma, A.N. 1999). This paper aims to investigate and present the potentials of POME as a resource that can contribute to world economic and sustainable development. Secondly how the palm oil mill operators are taking advantage of the emergent of the new PTT in changing the status of POME from waste to resource and at the same achieving zero discharge concepts in palm oil industry.

2. Wastes generated from palm oil mills

Concomitant production of huge wastes always results from processing of oil palm fresh fruit bunches (FFB) primarily for palm oil. Prasertan and Prasertan (1996) reported that during processing in palm oil mills, more than 70% (by weight) of the processed FFB is usually left over as oil palm wastes. The wastes products from oil palm processing consist of oil palm trunks (OPT), oil palm fronds (OPF), palm oil mill effluent (POME), empty fruit bunches

(EFB), palm press fibre (PPF), shell palm oil mill sludge (POMS), and palm kernel cake (PKC) (Aziz & Abdul, 2007; Singh, Hakimi & Esa, 2010).

According to Pleanjai et al. (2004), fibre, shell, decanter cake and EFB accounts for 30, 6, 3, and 28.3% of FFB respectively. Palm kernel oil (white palm oil) is obtained from the seed known as kernel or endosperm. When oil has been extracted from the kernel, what remains is known as palm kernel cake (PKC). This is rich in carbohydrate (48%) and protein (19%) as reported by Onwueme and Sinha (1991).

POME; “Waste or Resource’ which is the focus of this paper is generated mainly from oil extraction, washing and cleaning processes in the mills. POME consists of water soluble components of palm fruits as well as suspended cellulosic materials like palm fibre, fat, grease and oil residues (Agamuthu, 1995). However, Rupani et al. (2010) also argued that among the wastes that are generated from processing of oil palm fruits, POME is considered the most harmful waste to the environment if discharge untreated.

2.1 Records of POME generated from palm oil mills in Malaysia

Yacob et al. (2005) reported that about 26.7 million tonnes of solid biomass and an average of 30 million tonnes of POME were generated from 381 palm oil mills in Malaysia in 2004. Based on palm oil production in 2005 of 14.8 million tonnes, an average of about 53 million m^3 POME is being produced per year in Malaysia (Lorestain, 2006). According to Variappan and Yen (2008), 66.8 million tonnes of POME were generated in 2005. However based on the statistical value of total crude palm oil production (CPO) in May 2011, the production of 985, 065 tonnes of CPO means a total of 1.5 million m^3 of water was used, and 738,797 m^3 was released as POME in one month alone. But Yacob et al. (2005), also in their estimation stated that about 0.5-0.75 tonnes of POME would be generated from mill for every tonne of FFB. Consequently, for a well-run mill with good housekeeping, it is estimated that 2.5 tonnes of POME are generated for every tonne of CPO produced. Moreover, the national average is putat 3.5 tonnes of POME per tonne of CPO. Arguably, generation of POME will continue to rise in tonnes as production and processing of palm oil continue to rise to meet both domestic and global demand.

2.2Palm oil mill effluent (POME)

POME is a colloidal suspension originating from mixture of sterilizer condensate, separator sludge and hydro cyclone wastewater in a ratio of 9:15:1 respectively (Wu et al. 2010). According to Borja & Bank (1994); Ma & Ong (1985), about 2.5-3.0 tonnes of POME per tonnes of produced crude oil is obtained in the extraction processes.

POME, when fresh, is a thick brownish colloidal mixture of water, oil and fine suspended solids. It is hot (80-90^{oc}) and possess a very high Biochemical Oxygen Demand (BOD) which is non-toxic as no chemicals are added to the extraction process (Khalid & Wan Mustafa, 1992; Ma et al. 1993), and also acidic with a P^{H} of around 4.5 as it contains organic acids in complex forms that are suitable to be used as carbon sources (Md Din et al. 2006). However, Ho and Tan, (1983) reported that the suspended solids or particulate fraction of the effluent contribute with less than 50% to the total pollutant level.

In view of Ng et al. (1987), POME may vary considerable for different batches, days and factories, processing techniques and the age or type of fruit. While Ahmad et al. (2005, 2006), reported that nature of POME may as well depends on the discharge limit of the factory, climate and condition of the palm oil processing. Ahmad et al. (2003) noted that raw or partially treated POME has an organic matter which is due in part to the presence of unrecovered palm oil. This highly polluting wastewater according Ahmad et al. (2003), can cause pollution of water –ways due to oxygen level in rivers leads to anaerobic conditions and the release of noxious gases, particularly hydrogen sulphide. Thus, the natural ecology of the rivers is destroyed (Khalid & Wan Mustafa, 1992). Raw or untreated POME is characterized by high BOD often in the range of 25,000gm/l or higher as shown in table 1.

Table 1: Characteristics of palm oil mill effluent (POME)

Parameter	POME (Average)	Range
pH	4.2	3.4-5.2
Oil and grease	4,000	-
Biochemical oxygen demand (BOD)	25,000	10,250-43,750
Chemical oxygen demand (COD)	51,000	15,000-100,000
Total solids	40,000	11,500-79,000
Suspended solids	18,000	5,000- 54,000
Total volatile solids	34,000	9,000- 72,000
Ammonical nitrogen (NH3–N)	35	4- 80
Total nitrogen (T.N.)	750	180-1,400
Phosphorous (P)	180	-
Potassium (K)	2,270	-

Magnesium (Mg)	615	-
Calcium (Ca)	439	-
Boron (B)	7.6	-
Iron (Fe)	46.5	-
Manganese (Mn)	2.0	-
Copper (Cu)	0.89	-
Zinc (Zn)	2.3	-

*All values are in mg L-1 except pH

Source;http://www.mpob.gov.my/2012

2.3 Composition of POME

Composition of POME depends mainly on raw material quality, season and the particular operations being used at any given time. As stated earlier, POME when fresh is a thick brownish colloidal mixture of water, oil and fine suspended solids. It is hot (80-90^{oc}) and possesses high amounts of total solids (40,500gm/l), very high BOD of 25,000gm/l, Chemical Oxygen Demand (COD) of 50,000gm/l, oil and grease of 4,000gm/l (Ma, 2000).
Khalid & Wan Mustafa, (1992) and Ma et al. (1993) all reported that POME is non-toxic, as no chemicals are added during extraction process. However, POME is low in P^H because of the organic acids produced in the fermentation process; it is acidic with P^H of about 4.5 as it contains organic acids in complex forms that are suitable to be used as carbon source (Md Din et al. 2006). Ugoji, (1997) confirmed that POME consist of water soluble components of palm fruits as well as suspended materials like oil residues, short palm fibre, cell walls, organelles, a variety of carbohydrates ranging from cellulose to simple sugars, a range of nitrogenous compounds from proteins to amino acids, free organic acids and assembly of minor organic and mineral constituents.
Nutrients contains in POME as reported by Habib et al. (1997) and Muhrizal et al. (2006), are nitrogen, phosphorus, potassium, magnesium and calcium, which are all vital nutrients elements for plant growth. High content of A1 in POME as compared to chicken manure and composted sawdust was also reported by Muhrizal, (2006). According to Habib et al. (1997), toxic metals such as lead can also be found in POME, but James et al. (1996), argued that lead concentration are usually below sub lethal levels (> 17.5 ug/g) and in their view lead is found in POME as a result of contamination from plastic and metal pipes, tanks and containers where lead is widely used in paints and glazing materials.

POME, despite its biodegradability, cannot be discharged without first being treated because it is acidic and contains residual oil that cannot be easily separated using conventional gravity-based systems. Basically, this oily mix needs a lot of oxygen before it can decomposed completely, and this phenomenon is called having high biochemical oxygen demand, and raw POME can sometimes have BOD of up to 100 times higher than that of domestic sewage. Because POME still contains a significant amount of organic matter even when treated, still imposes a demand on the environment. Microbes in water take in dissolved oxygen as they digest organic matter. This demand for oxygen known as BOD is usually measured in milligrams per litre (mg/l) and is normally used as an indication of the organic quality or the degree of organic pollution of water. Basically a higher BOD means poorer quality, and the inverse holds true as well.

Consequently, it has been observed that the microbial population increases in proportion to the amount of food available. In such conditions, the microbial action will consume dissolved oxygen faster than atmospheric oxygen can dissolve in the water. Apparently, fish and other aquatic organism might die because the water body has been depleted of its oxygen.

3. POME as a waste

POME is a by-product of a processed FFB to obtain mainly palm oil and other major components. According to one of the definitions of wastes by Pongrácz and Pohjola, (1999), waste is a man-made thing, which in a given time and place, in its actual structure and state, is not useful to its owner, or an output that does not have any owner. Clearly, because millers in the past have not completely found useful purpose for POME, it is seen and considered as a waste and a burden to palm oil industry.Pongrácz and Pohjola (2004), stated in their view that, depending on the nature of a given waste, owners may be restricted in their ability to freely give up ownership. This lends further insight in to reasons why palm oil mills are restricted or regulated by environmental regulatory authorities when it comes to discharge or disposal of POME by palm oil mills. This is obviously due to the pollutant nature of the raw or untreated POME.

Although, new methods and technologies have been developed to find approachable solutions for POME management yet, palm oil mills are still struggling to meet up with more stringent limits of effluent discharge allowed by Department of Environment (DOE) Malaysia. However, these challenges faced palm oil mills can be overcome if POME can be re-defined as a secondary raw material as supported by Jacobs (1997), assertion that a “by-product or residual product does not constitute waste if it is destined for direct re-use in a further process in its existing form and if the use of a residue as a substitute or ingredient is as environmentally sound as the material it is replacing".

To this end Pongrácz (2000), defined non-waste as an object that has been assigned a purpose by its (or a potential) owner, and this owner will either use it for that purpose, or by adjustment of state or structure to ensure that the object will be able to perform in respect to the assigned purpose. According to Pongrácz and Pohjola (2004), non-waste definition introduced by Pongrácz (2002) was necessary to avoid obstacles to resource conservation due to materials being considered waste. Pongrácz and Pohjola (1997), argued that waste is created as an unwanted but not avoided output with no purpose. In their view, waste is process-specific and can be avoided or minimised by changing the process performance and therefore most industrial processes that are aiming at a specified output often produce undesired by-products that we call waste (Pongrácz and Pohjola, 2004).

The new agenda for waste management focuses upon the development of more appropriate, sustainable definitions of waste, so that what is now commonly perceived as being waste will in fact be increasingly seen as resource-rich, "non-waste" (Pongrácz and Pohjola, 2004). Under the present definition of waste, which POME is also categorized, recoverable material or substance like POME is seen more as a potential pollutant rather than as a potential raw material or resource. The emergent of the new biotechnological advances and POME treatment technologies, like POMETHANE, has changed the status of POME from being a waste to non-waste or resource. Consequently, the use of current advance technologies to manage POME by mill operators will not only turn POME to resource but also means of achieving zero discharge concept been champion by environmentalist worldwide.

4. POME as a resource

Resource according to Wikipedia is a source or supply from which benefit is produced. Typically resources are materials, money, services, staff or other assets that are transformed to produce benefit and in the process may be consumed or made unavailable. The question is can POME, a by-product of a processed FFB fit into above definition of resources? This paper explores the potentials of POME as a resource rather than just a by-product or waste.

What is required for POME to achieve this feat, according to Wu et al. (2009) is to adopt an international trend of promoting pollution prevention through cleaner production, which is based on the 5R policy. Therefore, the introduction of the emerging 5R policy namely; reduction, replacement, reuse, recovery and recycling into POME management through environmentally sound biotechnologies will change the status of POME from waste to resource.

The use of biotechnological advances and advance POME treatment technology in the sustainable reuse and recovering of POME has redefined and changed POME from being a waste to a valuable resource of different forms. Wu et al. (2006) and Suwandi (1991) pointed out the possibility of recovering and concentrating the available bio resources in POME by an ultrafiltration process in order for the concentrated bio resources to be reused more effectively as fermentation media, fertilizers and animal feeds. POME has also been successfully converted to energy through an anaerobic thermophilic digestion process which maximizes the yield of biogas production. The process captures the methane from POME to run a gas engine to generate electricity or alternatively turn the biogas in a boiler to generate steam and hot water.

4.1 Fermentation media from POME

POME and its derivatives have been exploited as fermentation media to produce various products or metabolites such as antibiotics, bio insecticides, solvents (Acetone-Butanol-ethanol; ABE), polyhydroxyalkanoates (PHA), organic acids as well as enzymes to varying degree of success (Wu et al. 2007). The hydrogen production from POME during anaerobic treatment has also been intensively studied (Atif et al. 2005; Vijayaraghavan & Ahmad 2006). In addition, it has been reported that POME also contains certain powerful water-soluble antioxidants phenolic acids and flavonoids (Wattanapenpaiboon & Wahlqvist, 2003).

According to Hwang et al. (1978); Phang (1990) and Habib et al. (1997), the possibility of reusing POME as fermentation media is largely due to the fact that POME contains high concentration of carbohydrate, protein, nitrogenous compounds, lipids and minerals. Results of various studies on fermentation media such as antibiotics, bio insecticides, PHA, ABE, organic acid, enzymes and hydrogen from POME have been reported by; Lin et al. (2005); Uzel et al. (2005); Jamal et al. (2005); Takriff et al. (2005); Md Din et al. (2006); Masngut et al. (2007); Hipolito et al. (2007).

4.2 POME as a fertilizer

The potential for using POME as a cheap organic fertilizer that may offer an alternative to the excessive application of chemical fertilizers was reported by Wu et al. (2009). Oviasogie & Aghimien (2003), in their work confirmed that a proper use and safe disposal of POME in the land environment would lead to improved soil fertility and contribute to environmental sustainability. Their results showed an enrichment of soils with regards to phosphorus, nitrogen, calcium, magnesium, sodium and potassium following the application of the POME. Copper, iron and lead were said to be predominant in their organic forms, while zinc was particularly present in its exchangeable form.

Wu et al. (2009) reported that biologically treated POME has been widely used in the oil palm plantations for irrigation purposes and can be employed as a liquid fertilizer. It is estimated according to Wu et al. (2009), that each 15 million tonnes of POME would have a fertilizer value of RM 95.41 million ($31.80 million) (Table 2).

Table 2: Estimated fertilizer values from POME, which is based on 15 million tonnesof POME (Wu et al. 2009)

Fertilizer	Tonnes (x 100)	December 2002 price (RM/ton)($)	Fertilizer value (RM million)($)
Ammonium sulphate	75.5	580 (195)	43.79 (14.60)
Rock phosphate	19.5	545 (181)	10.63 (3.50)
Muriate of potash	68.6	250 (83)	17.15 (5.72)
Kieserite	59.6	400 (133)	23.84 (7.95)
Total			95.41 (31.80)

However, Wood et al. (1979) reported that an application of POME at 4.5 x $10^6$1 per applied hectare was estimated to represent a fertilizer application of about 30kg ammonium sulphate, 7kg rock phosphate, 52kg potash and 18kg kieserite per palm per year. The nutrient composition of POME as fertilizer is shown in (Table 2).

According to Chan et al. (1980), the use of POME has been shown to improve soil productivity and increase the yield of crops as well as contribute to better root health by improving the soil structure. Results of many other works on POME as fertilizer was also reported by; Aisueni & Omoti (2002); Salètes et al. (2004); Muhrizal et al. (2006); Guo et al. (2007).

4.3 Use of POME as a live food for animals and aquaculture organisms

According to Wu et al. (2009), POME as a dietary substitute for pigs, poultry and small ruminants as well as aquaculture organisms is gaining importance. Devendra (2004) reported that in Colombia, POME has been fed with good results directly to pigs (10-12 1/head/day) together with palm oil and other ingredient.

The Malaysian Agricultural Research Development Institute (MARDI) proved that wastes from the palm oil industry (such as oil palm sludge and palm press fibre) alone or in combination, dried to moisture contents of 7% could be used as supplementary food for sheep (Devendra and Muthurajah, 1976). Hutagalung et al. (1977) in their work investigated the use of POME as animal feed for growing-finishing pigs, in which case two types of "meals" known as censor tk8 (35% palm oil sludge, 32.5% cassava root meal, 32.5% palm kernel cake) and tk9 (32% palm oil sludge, 34% cassava root meal, 17% palm kernel cake, 17% grass meal) were used.They argued that it was economical to replace 50% maize (which is the regular diet constituent) with a POME-based animal feed, thus saving up to RM 0.02 ($0.01) per pig per day. This lends further support to the view that animal feed production from palm oil waste can replace at least half of the amount of imported maize for poultry diets and up to 100% for pig diet.

The nutritive values of a POME product known as "Prolima" as a protein source in broiler chicken diets was investigated by Yeong et al. (1980). They observed that the amino acid content of palm kernel cake and palm oil sludge were somewhat close to cereal by-products and that of "Prolima" was between soybean meal and peanut meal, in which case the overall percentage of amino acid availability for palm kernel cake, palm oil sludge and "Prolima" were 74.4%, 24.8% and 71.0% respectively. It was also argued in the foregoing that, the concentrations of "Prolima" up to 30% could be included in broiler diets as a replacement for soybean meal without causing any adverse effect on the growth performance of the chickens (Yeong et al. 1980).According to Habib et al. (1997), POME could also be reused as a food source by aquatic organisms such as chironomid larvae known as "bloodworms". They reported that production of chironomid larvae was significantly higher in POME (580g/20l POME) than in algal cultures (35g/20l algal culture). These chironomid larvae, in turn, present valuable live food for fish or cultured invertebrates (Shaw & Mark, 1980; Yusoff et al. 1996).

Results of other early researches on reuse of POME as animal feeds and aquaculture organisms were also reported by; Babu et al. (2001); Pasha (2007).

4.4 POME as an energy source

Ponding or open lagoon system for treating POME in Palm oil mills in Malaysia have been in existence for a very long time. The pond systems have been applied in Malaysia for POME treatment since 1982 and they are classified as waste stabilization pond (Onyia et al. 2001). Parveen et al. (2010), reported that more than 85% of palm oil mills exclusively use ponding system due to their low cost and simple operational systems.Therefore, ponding system was the most conventional method for treating POME (Khalid & Wan Mustafa, 1992). Then, there was an introduction of close aerobic and anaerobic digestion tank or treatment in the management of POME to meet up with the discharge limits allowed. According to Perez at al. (2001), anaerobic process is a suitable treatment method due to the organic characteristics of POME.

However, all the methods that are employed by mills for digestion of POME always produce or generate biogas as a by-product. But amount of biogas generated largely depends on the particular method used. In open tank digestion system, Yacob et al. (2005) reported that every tonne of treated POME, an average of 5.5kg of methane (or approximately 36% of biogas) is emitted from open digesting tanks. This value is significantly lower than what was reported by Ma et al. (1999), that is 65%. In total, an average of 5.4 1/min m^2 biogas was recorded and total methane emission per open digesting tank was 518.9kg/day.

According to Ng et al. (2011), it is estimated that 1 tonne of FFB processed will generate 0.67 tonne of POME, and each tonne of POME is able to produce $28m^3$ of methane. Organics, a company involved in project design to recover energy from POME also published that a typical mill rated at 40 tonne per hour FFB can produce between 1 and 2 Mega Watt (MW) of electricity from the biogas that can be generated in an anaerobic digester. (www.organics.com). Biogas, a by-product of anaerobic degradation of POME consist of about 65% methane, 35% carbon dioxide, and trace of hydrogen sulphate. Ahmad et al. (2011), reported that based on a study on Clean Development Mechanism (CDM), potential in the waste sectors (for energy source), it was found that the most potential is where anaerobic degradation takes place within the municipal landfills and POME ponds.

Table 3: Power and heat potential from CDM projects waste sectors. (S. Ahmad et al. 2011)

Waste sectors (Mt/yr)	**Methane recovery potential (Mt/yr)**	**Total technical power potential (MW)**	**Feasible total installed capacity (MW)**
MSW landfill	176,000	173	45
POME	245,000	330	160
Swine farming	35,500	46	23
Other industries (wastewater)	8000	35	7
Sewage	Negligible	Negligible	Negligible

The potential sizes of recovery and its relative power and heat potential for feasible projects are presented in Table 3.

Therefore, POME is another potential energy source from which the methane gas or biogas released during anaerobic digestion can be collected for power generation (Wendy et al. 2012).To date; there are 411 local palm oil millers with the potential to be Independent Power Producers (IPPs) of sustainable green energy through utilization of methane from POME. Based on these potentials, it has long been suggested that Sabah could look at its palm oil mills as a source for electricity to overcome the power shortage supply especially in its east coast.Regrettable, more than 90% of the palm oil mills in Malaysia have been wasting this essential resource by its emission into the atmosphere, there by polluting our environment and contributing to global warming. However, complete lack of technology by palm oil mills to harness this biogas was the major reason for this unacceptable phenomenal in the oil industry.

Consequently, the development and introduction of new advance POME treatment technology for management of POME, has presented a new platform to change the trend. It is now possible for palm oil mills to generate, collect and utilize methane as energy source while treating POME. Many companies involved and specialized in liquid waste treatment have lunched the new advance POME treatment technology. Some of these companies, especially within the Southeast Asia have already entered into project agreement with some of the palm oil mills in Malaysia. Camco Southeast Asia, a regional clean energy company has completed arrangement to build a 2 MW biogas plant that will make use of methane pollutants generated from anaerobic digestion of POME. The $4 million project is part of 13 years "build-own-operate-transfer" agreement between Camco and a palm oil mill in Malaysia. Under the term of agreement, the miller owner will provide adequate POME feedstock for free for the entire duration of the contract.

In a related development, Kubota Corporation has also received a turnkey order for biogas recovery plant and POME treatment plant from a new palm oil mill in Bintulu, Sarawak, Malaysia. In 2012, Felda Global Ventures Holdings announced its readiness to install POME-to-biogas plant. The RM 8 million (€ 2 million) pilot plant according to Felda will be built in Kota Tinggi, Johor by Weida Bhd. The biogas will be used to generate 2 MW of electricity that will be sold to Tenega Nasional Bhd. In addition, Felda has also chosen Veolia Water Solutions and Technology to deliver a turnkey installation consisting of a biogas plant to treat POME generated from Serting Hilir palm oil mill. The biogas plant as reported by the company will generates about 1.2MW electricity per hour, and the electricity generated will be supplying the mill's production and will also be connected to the grid of the local energy provider (Tenaga Nasional Bhd). Also taking advantage of this new technology for POME management through CDM projects are Alambumi palm oil mill Sdn Bhd Miri and Rinwood Pelita palm mill Mukah.

5. Conclusion

Some of the major obstacles to adoption of cleaner solutions in POME management in palm oil mills have been the total absence of sustainable technology and compelling economic arguments. Conclusively, these are the main reasons why POME has been treated and handled by millers as waste instead of resource.

Apart from turning POME into resource, the new biotechnology advances and POME treatment technology like POMETHANE, has provided a new sustainable opportunity to improve the palm oil industry environmental performance toward a responsible model of sustainable production. Therefore, POME should be considered a valuable resource, and recovering it for other uses is much more preferable environmental alternative than the current treatment and disposal.

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