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Pollution Control: How Feasible is Zero Discharge Concepts in Malaysia Palm Oil Mills

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***Abstract:* -** Many palm oil mills in Malaysia still discharged either partially treated or raw palm oil mill effluent (POME) into nearby rivers. Either partially treated or untreated POME depletes a water body of its oxygen and suffocates aquatic life. Vast amounts of biogas are also generated during anaerobic digestion of POME. This paper presented the key findings from the survey mailed to 86 palm oil mills located in Sarawak and Sabah. The survey results provide an overview of the position of the palm oil mills operators on current advance POME treatment technology (PTT) in relation to achieving zero discharge concepts. The survey attempted to identify the key issues about the PTT in respect to feasibility of zero discharge concepts in palm oil mills. The results shows that, although palm oil mills generate a lot of different types of wastes during processing of Fresh Fruit Bunches, according to the operators and available literature, POME is the most difficult waste to manage. The results also shows that, palm oil mills cannot meet up with the new discharge limits of 20ppm of BOD and zero emission using only conventional open or closed pounding system.

***Keywords:* -** *Anaerobic digestion, Biogas, Palm oil mill, Palm oil mill effluent, Zero discharge concept*

I. INTRODUCTION

The global market has become increasingly dependent on palm oil, but major producers like Malaysia and Indonesia are facing tougher operational challenges to cater for the rapidly growing global demand. Among the major challenges faced by palm oil industry especially in developing countries like Malaysia are environmental issues. The processing of oil palm fresh fruit bunches (FFB) primarily for palm oil also results in concomitant production of wastes in the forms of palm oil mill effluent (POME), empty fruit bunches, mesocarp fiber and shell. POME consists of water soluble components of palm fruits as well as suspended materials like palm fiber and oil residues. Despite its biodegradability, POME 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. Essentially, this oily mix needs a lot of oxygen before it can decompose completely, and this phenomenon is called having a high biochemical oxygen demand (BOD). In the past, when the industry was at its infancy in 1960's, either palm oil mills usually discharged partially treated or raw POME into nearby rivers as this was the easiest and cheapest method for disposal. However, excessive quantities of untreated POME deplete a water body of its oxygen and suffocate aquatic life, and many rivers have been devastated by such discharges. The problem of pollution accruing from a mere 92,000 tonnes production by only 10 mills was not apparent then. The environment could somehow absorb these wastes.

This lackadaisical attitude did not last long. By the 1970's the growth of the industry was literally exponential, bringing along with it pollution which the waterways could no longer handle, so much so that palm oil processing became synonymous with POME pollution. Ton for ton, the oxygen depleting potential of raw POME is 100 times that of domestic sewage. The industry was faced with a major problem, virtually completely lacking in any proven technology to treat POME. Committed to overcome the problem, the government and the industry worked together to source for treatment technologies that are environmentally and economically sound. Bear in mind, none was available anywhere in the world then to specifically treat POME. This government-industry synergy towards common goal-pollution abatement paid off handsomely. Systems for treatment of organic industrial wastes were successfully adapted for POME treatment. The three most commonly used systems were ponding system, open tank digester and extended aeration system, and closed anaerobic digester and land application systems. [1].

Although particular aspects of environmental control had been the subject of legislation in past decades around the world, for example the Control of Pollution Act 1974, Trade Effluent Regulations 1989, and the Environmental Protection Act 1990 which raised significantly the profile of the environment as an industrial responsibility and which brought many industrial activities under the direct control of the Environment Agency or local authorities in U.K [2]. However, the growing international concern about the environmental sustainability, public awareness and community involvement in the protection of their immediate environment has continue to mount more pressure on manufacturing industries especially palm oil mills in Malaysia to control environmental pollution.

Sporadic research has been performed and new methods and technologies have been developed to find approachable solutions for managing POME, yet 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 Biological Oxygen Demand (BOD), a measure of effluent strength, to 100 parts per million (PPM). However, in environmentally sensitive areas of Sabah and Sarawak like Kinabatangan River, Department of Environment (DOE) Malaysia had imposed a more stringent condition of 20 ppm since 2006. For example, for new mills, a 20-ppm BOD requirement coupled with land irrigation has been imposed in Sabah. In very sensitive areas, the DOE has even imposed a zero discharge requirement

There are more than 430 palm oil mills in Malaysia, of which 55 mills are in Sarawak and 124 mills in Sabah, making the state the largest crude palm oil (CPO) producer in Malaysia [1]. Based on these new challenges being faced by palm oil mills, there is urgent need for the palm oil mills in Malaysia to explored and take advantage of the current available options or additional alternative to improve their environmental performance. This paper provides the outcome of the preliminary studies carried out on the feasibility and sustainability of the palm oil mills acquiring and adopting the zero discharge technology to achieve zero discharge concepts.

II. WORLD PALM OIL PRODUCTION

Nigeria was the largest exporter of palm oil and palm kernels until 1934 when the country was surpassed by Malaysia. Malaysia and Indonesia had surpassed Africa's total palm oil production. According to oil palm review, published by the Tropical Development and Research Institute (TDRI) in the United Kingdom, over 3 million tonnes of palm oil was produced by Malaysia alone in 1983, compared with about 1.3 million tonnes of Africa production. In 1995, Malaysia was the world's largest producer with a 51% of world share, but since 2007, Indonesia has been the world's largest producer, supplying approximately 50% of world palm oil volume.

Worldwide palm oil production during the 2005-2006 growing season was 39.8 million metric tonnes, of which 4.3 million tonnes was in the form of palm kernel oil. However many economists predict palm oil will be the leading internationally traded edible oil by the year 2012. Table 1.2 is records of 2012 world palm oil production [3]

Table 1.2; 2012 World Palm Oil Production [3]

Rank	Country	Production (1000 MT)
1.	Indonesia	28, 000.00
2.	Malaysia	19, 000.00
3.	Thailand	1,700.00
4.	Colombia	900.00
5.	Nigeria	850.00
6.	Papua New Guinea	530.00
7.	Ecuador	510.00
8.	Cote'd Ivoire	300.00
9.	Brazil	275.00
10.	Honduras	252.00

2.1. Production of Palm Oil and Palm Kernel Oil in Malaysia

Palm oil production in Malaysia has increased over the years, from 4.1 million tonnes in 1985 to 6.1 million tonnes in 1990 and to 16.9 million tonnes in 2010. It reached 18.9 million tonnes in 2011 and in 2012 the production was estimated to be at 19.4 million tonnes [3]. The Malaysian palm oil industry easily meets the local oils and fats demand, and the excess are exported. Palm kernel oil production in 1999 was 1.3 million tonnes, and reached 4.7 million tonnes in 2011. Prior to 1970, most of the palm kernels produced was exported. Since 1979, they were crushed locally to produce crude palm kernel oil and palm kernel cake. Malaysia currently accounts for 39 % of world palm oil production and 44% of world exports. If taken into account of other oils & fats produced in the country, Malaysia accounts for 12% and 27% of the world's total production and exports of oils and fats. Being one of the biggest producers and exporters of palm oil and palm oil products, Malaysia has an important role to play in fulfilling the growing global need for oils and fats sustainably. [1].

III. GENERATION OF WASTES FROM PALM OIL MILLS

The processing of oil palm fresh fruit bunches (FFB) primarily for palm oil also results in concomitant production of wastes. According to [4], during processing in palm oil mill, 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 fiber (PPF), shell, palm oil mill sludge (POMS), and palm kernel cake (PKC) [5, 6] According to [7] fiber, shell, decanter cake and EFB accounts for 30, 6, 3, and 28.3% of the 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%) [8]. POME is generated mainly from oil extraction, washing and cleaning processes in the mill and these consists of water soluble components of palm fruits as well as suspended cellulosic materials like palm fiber, fat, grease and oil residues [9]. Among the wastes that are generated from processing of oil palm fruits, POME is considered the most harmful waste for the environment if discharged untreated. [10].

3.1. Records of Generation of Pome by Palm Oil Mills in Malaysia

It has been estimated 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 [11]. Based on palm oil production in 2005 of 14.8 million tonnes, an average of about 53million m^3 POME is being produced per year in Malaysia [12]. However [13], reported that 66.8 million tonnes of POME were generated in 2005. Based on the statistical value of total CPO production in May 2011, the production of 985,063 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 that month alone. [11], in their estimation stated that about 0.5- 0.75 tonnes of POME would be generated from mill for every ton of fresh fruit bunch. However, for a well-run mill with good housekeeping, it is estimated that 2.5 tonnes of POME are generated for every ton of CPO produced. However, the national average is about 3.5 tonnes of POME per ton of CPO. This is an indication of increase in generation of POME in tonnes as production and processing of palm oil continue to rise to meet both domestic and global demand.

3.2. Palm Oil Mill Effluent (POME)

The extraction of palm oil involves a number of steps; fruit bunch sterilization, stripping, digestion, pressing, clarification, purification, and vacuum drying. When these entire steps are added together, a significant amount of water is needed for a palm oil mill’s operations. On average, it is estimated that for 1 ton of crude palm oil produced, 5-7.5 tonnes of water are required, and more than 50% of the water will end up as POME [14]. Raw POME is a colloidal suspension containing 95%-96% water, 0.6-0.7% oil and 4-5% total solids including 2-4% suspended solids that are mainly consisted of debris from palm fruit mesocarp generated from three main sources, namely sterilizer condensate (36%), separator sludge or clarification (60%) and hydro cyclone (4%) wastewater [15, 16]. The typical characteristic of individual wastewater streams coming out of palm oil mill from the three main source of generation is given in Table 2.3[17]

Table 2.3: Characteristics of individual wastewater streams [17]

Parameters	Sterilizer condensate	Oil clarification wastewater	Hydro cyclone wastewater
pH	5.0	4.5	-
Oil & Grease	4,000.0	7,000.0	300
BOD; 3-day, 30°C	23,000.0	29,000.0	5,000
COD	47,000.0	64,000.0	15,000
Suspended solid	5,000.0	23,000.0	7,000
Dissolve solid	34,000.0	22,000.0	100
Ammonical Nitrogen	20.0	40.0	-
Total Nitrogen	500.0	1,200.0	100

* All the units are in mg/L except for pH

The raw or partially treated POME has an organic matter, which is due in part to the presence of unrecovered palm oil [14]. This highly polluting wastewater can therefore cause pollution of waterways due to oxygen depletion and other related effects as reported by [14]. The depletion of the 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, [18]. In Malaysia, POME produces 25 million tonnes per year of chemical oxygen demand (COD), [19].

3.3. Characteristics of POME

POME composition depends mainly on the season, raw material quality and the particular operations being conducted at any given time. POME, when fresh, is a thick brownish colloidal mixture of water, oil and fine suspended solids. It is hot (80-90 0^{C}) and possesses high amounts of total solids (40,500 mg/l), very high Biochemical Oxygen Demand (BOD) (25,000 mg/l), Chemical Oxygen Demand (COD) (50,000 mg/l), oil and grease (4,000 mg/l), [16]. The effluent is non-toxic, as no chemicals are added to the extraction process [18, 20]. Typically, POME is low in P^{H} because of the organic acids produced in the fermentation process; it is 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 [21]. POME consists of water soluble components of palm fruits as well as suspended materials like oil residues, short palm fiber, 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 [22]. Nutrients contains in POME according to [23] and [24], are nitrogen, phosphorus, potassium, magnesium and calcium, which are the vital nutrient elements for plant growth.

Due to the non-toxic nature and fertilizing properties, POME can be used as fertilizer or animal feed substitute, in terms of providing sufficient mineral requirements.
[24] reported that POME contains high content of A1 as compared to chicken manure and composted sawdust According to [23], toxic metals, such as lead (Pb), can also be found in POME, but [25], reported that Pb concentrations are usually below sub lethal levels (>17.5 ug/g). According to [24], Pb is found in POME as a result of contamination from plastic and metals pipes, tanks and containers where Pb is widely used in paints and glazing materials.

Despite its biodegradability, POME 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. Essentially, this oily mix needs a lot of oxygen before it can decompose completely, and this phenomenon is called having a high biochemical oxygen demand (BOD), and raw POME can sometimes have a BOD of up to 100 times higher than that of domestic sewage.

POME even when treated, still imposes a demand on the environment as is still contains a significant amount of organic matter. Microbes in water take in dissolved oxygen as they digest organic matter. This demand for oxygen known as biochemical oxygen demand (BOD) is usually measured in milligrams per liter (mg/l) and is widely used as an indication of the organic quality or the degree of organic pollution of water; a higher BOD means poorer quality, and the inverse holds true as well.

Generally, the microbial population increases in proportion to the amount of food available. In such instances, the microbial action will consume dissolved oxygen faster than atmospheric oxygen can dissolve in the water. When that happens, fish and other aquatic life might die because of depleted oxygen. Raw or untreated POME is characterized by high BOD, often in the range of 25,000gm/l or higher as shown in Table 2.3.

3.4. Pollution by POME from Palm Oil Mills

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 generation from palm oil mills have been declared as one of the major source of environmental pollution. For every metric ton of palm oil produced, 2.5metric tonnes of effluent (POME) are generated from processing in palm oil in mills. Direct release of this effluent causes freshwater pollution, which can affect downstream biodiversity and people [26]. In Malaysia, the total production of crude palm oil in 2008 was 17,734,441tonnes.

However, the production of this amount of crude palm oil results in even larger amounts of palm oil mill highly polluting effluent that were mostly discharged directly into environment especially by small and medium palm oil mills operators. In 1983, more than 7.5 million metric tonnes of POME was generated in Malaysia and POME has been singled out as the chief contributor to Malaysia's environmental pollution. [27].

Palm oil mills discharged palm oil effluent into environment in its raw form. Studies on the effect of palm oil effluent on soil showed that raw POME is acidic and alters microbiological and physico-chemical properties of soil, which ultimately affects soil fertility. [28]. Anthropogenic release of greenhouse gases (CO_2 and CH_4) from palm oil mills during anaerobic digestion of POME has been recognized as one of the main causes of global warming which contribute to climate change all over the world. Several measures under the Kyoto Protocol 1997 have been drawn up to reduce the greenhouse gases emission. One of the measures is Clean Development Mechanisms (CDM). In Malaysia, palm oil industry particularly from palm oil mill effluent (POME) anaerobic treatment has been identified as an important source of methane. In a research to investigate the actual greenhouse gases emission from Lagoons and open digesting tank in palm oil mills, the result indicated that methane contribution to biogas released from the open digesting tank and lagoon system were 35% and 45% respectively. Also in a study to quantify the actual CH_4 emission from the open digesting tanks in Felda Serting Hilir palm oil mill Malaysia, the CH_4 emission pattern recorded for 52 weeks from 3600 metric tonnes was between 13.5% and 49.0%. The total CH_4 emission per open digesting tank was 518.9kg per day [29]. Consequently, similar situations have been reported in countries like Thailand, Indonesia, and Nigeria that are into large-scale palm oil production.

IV. CHALLENGES FACED BY PALM OIL MILLS

The United Nations Conference on Environment and Development (UNCED) 1992 in chapter 21 of its Agenda 21 observed that environmentally sound management of waste to control environmental pollution was among the environmental issues of major concern in maintaining the quality of Earth's environment and especially in achieving environmentally sustainable development in countries of the world. It went further to say that effective control of generation, storage, treatment, recycling and reuse, transport, recovery and disposal of wastes is of paramount important for health, environmental protection, natural resource management and sustainable development. It therefore becomes imperative for the palm oil mills to have modern, advance, and sustainable technologies to handle and manage its waste in a proper and environmentally sound manner to control environmental pollution. There is no gain in improving the economic and welfare of the people and only for them and their environment to be polluted because of indiscriminate discharge of waste especially POME by palm oil mills.

In the past, when the industry was at its infancy in 1960's, palm oil mills usually discharged either partially treated or raw POME into nearby rivers as this was the easiest and cheapest method for disposal. However, excessive quantities of untreated POME deplete a water body of its oxygen and suffocate aquatic life, and many small rivers have been devastated by such discharges. The problem of pollution accruing from a mere 92,000 tonnes production by only 10 mills was not apparent then. The environment could somehow absorb these wastes.

This lackadaisical attitude did not last long. By the 1970's the growth of the industry was literally exponential, bringing along with it pollution which the waterways could no longer handle, so much so that palm oil processing became synonymous with POME pollution. Tone for ton, the oxygen depleting potential of raw POME is 100 times that of domestic sewage. The industry was faced with a major problem, virtually completely lacking in any proven technology to treat POME. Committed to overcome the problem, the government and the industry worked together to source for treatment technologies that are environmentally and economically sound. Bear in mind, none was available anywhere in the world then to specifically treat POME. This government-industry synergy towards common goal-pollution abatement paid off handsomely. Systems for treatment of organic industrial wastes were successfully adapted for POME treatment. The three most commonly used systems were ponding system, open tank digester and extended aeration system, and closed anaerobic digester and land application systems. [1]. However, the growing international concern about the environmental sustainability, public awareness and community involvement in the protection of their immediate environment has continue to mount more pressure on manufacturing industries especially palm oil mills in Malaysia to control environmental pollution.

Malaysia has been identified as the country that produces the largest POME pollution load in the river [13]. Due to this fact, the palm oil industry faces the challenge of balancing the environmental protection, its economic viability and sustainable development. Therefore there is urgent necessity to find an approach to preserve the environment while keeping the economy growing.

Sporadic research has been performed and new methods and technologies have been developed to find approachable solutions for managing POME, yet 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 BOD, a measure of effluent strength, to 100 parts per million (PPM). However, in environmentally sensitive areas of Sabah and Sarawak like Kinabatangan River, Department of Environment (DOE) Malaysia had imposed a more stringent condition of 20 ppm since 2006. For example, for new mills, a 20-ppm BOD requirement coupled with land irrigation has been imposed in Sabah and in very sensitive areas; the DOE has even imposed a zero discharge requirement.

Over the last two decades, several treatment and disposal technologies have been successfully developed and used to treat POME [30]. They were all designed and constructed to meet a discharge limit of 100mg per liter BOD. They consist of conventional biological systems using anaerobic and aerobic or facultative processes. If operated according to design criteria and maintained well, the processes are able to treat POME to the discharge limits set by the DOE Malaysia.

Although, anaerobic digestion is the most suitable method for the treatment of effluents containing high concentration of organic carbon such as POME [31]. Anaerobic digestion according to [32], has been proven unique and the most beneficial stabilization technique as it optimizes cost effectiveness, is environmentally sound, minimizes the amount of final sludge disposal, and has the ability to produce a net energy gain in the form of methane (CH_4). The processes, being biological, rely on suitable bacteria to break down the organic matter (pollutants) and, consequently, reduce the BOD of the effluent. The end- products of anaerobic degradation are biogas (consisting of about 65% methane (CH_4), 35% carbon dioxide (CO_2) and trace amounts of hydrogen sulphide) and sludge. At the mill, POME is collected in a sludge pit and retained for a day or two to allow the residual oil to rise and be skimmed off before being pumped to a treatment plant. It is important to ensure that as little oil as possible gets into the treatment plant as; otherwise, the efficiency of treatment will be compromised. Anaerobic digestion of POME generates vast amounts of biogas, about 28 cubic meters per ton of POME treated. Both CH_4 and CO_2 are greenhouse gases and CH_4 is more potent. Biogas is also corrosive and odorous. Thus its emission to environment is undesirable and this has been seen as the main disadvantage and challenges faced by palm oil mills in the use of anaerobic method for treatment of POME. However, production and recovery of biogas during anaerobic digestion of POME can be turn into economic advantage and means of achieving zero discharge concepts if the palm oil mills would acquire and adopt available current advance technologies that have capacity to harness biogas for heat and electricity generation.

This study, apart from its quest to establish the feasibility of zero discharge concepts in palm oil mills. It also explored the challenges faced by palm oil mills in their effort to meet up with new stringent regulations and growing awareness of need not to pollute. Consequently a reliable and sustainable means of achieving this fits as mentioned earlier is by acquiring and adopting of current advance POME treatment methods or technologies that can harness the biogas that are generated during anaerobic digestion of POME. This has been agreed as one of the best environmental practices that will guaranty zero discharge concepts.

V. POLLUTION CONTROL AND ZERO DISCHARGE CONCEPTS

United States America (USA) congress, the United States Environmental Protection Agency (EPA), and environmental professionals concluded in the 1980s that a new industrial waste management philosophy was needed if the ever-expanding industrial pollution and resource depletion problems were to be solved, [33]. They argued that indiscriminate use of virgin resources in manufacturing and subsequent end-of –pipe treatment of resulting wastes would not provide the resource sustainability and environmental quality demanded by the public. As a result, a new paradigm was developed which emphasized minimizing the use of harmful or overexploited resources and eliminating or minimizing waste production at the source in the industry's product area. This philosophy became known by many names, including waste minimization, source reduction, waste reduction, green engineering, and sustainable engineering, but the name that is most often associated with it is pollution control.

Pollution control is a term used to described production technologies and strategies that result in eliminating or reducing waste streams. The U.S. EPA defines pollution control or prevention as; the use of materials, processes or practices that reduce or eliminate the creation of pollutants or wastes at the source. It includes practices that reduce the use of hazardous materials, energy, water or other resources and practices that protect natural resources through conservation or use that is more efficient. .

Thus, pollution control includes both the modification of industrial processes to minimize the production of wastes and the implementation of sustainability concepts to conserve valuable resources. However, “zero discharge concepts” is a new idea, strategy, or proposal that involved an industrial processes design, pollution control plan, and or environmental management system to prevent release of any harmful or toxic material to the environment. (Authors). Pollution control activities range from product change to process changes in method of operation. The main premise underlying pollution prevention according to [35], that it makes far more sense for a generator not to produce waste than to develop extensive treatment schemes to ensure that the waste poses no threat to the quality of the environment and this assertion is likened to “zero discharge concept” which this study seeks to establish its possibility in palm oil mill industry in Malaysia that is striving hard to change its present image as environmental polluters.

VI. RESEARCH METHODOLOGY

Data for this research were collected between September 2012 to March 2013 by means of a questionnaire survey mailed to 86 palm oil mills located in both Sarawak and Sabah in Malaysia as a pilot project. The questionnaire explored a range of issues relating to the treatment and management of palm oil mill effluent (POME). In this research, emphasis was placed on the type(s) of technologies palm oil mills are presently using for POME treatment and most importantly focused on the possibility and feasibility of palm oil mills in Malaysia acquiring and adopting the current advance POME treatment technologies to achieve clean production and ultimately zero discharge concepts.

The response rate of 58% was achieved. The questionnaire explored the following aspects of POME treatment and management in palm oil mills;

- Is POME the most difficult waste to handle by palm oil mills?
- Which method(s) or technology does palm oil mills used in treating POME?
- Knowledge of availability of current advance POME treatment technologies by palm oil mills.
- Willingness of the palm oil mills to acquire current advance POME treatment technology as option for clean production and means of achieving zero discharge concepts.

The responses received were coded and entered into the SPSS database and analyzed using mean, ANoVa, t-test and correlation functions since in this research, what [36] referred to as complex research approach (combination of more than one type of research approach) was adopted. However, according to [37], a number of studies have been reported in the literature, including [38], [39], [40], [41], [42], [43], and [44]; all supports the use of means, percentage and frequency to be used as part of analysis especially for descriptive or exploratory studies.

Consequently, review of the case studies, pilot projects on current advance POME treatment technology in Malaysia palm oil mills and analysis of the data obtained from the palm oil mills formed the direction and position of this study on the feasibility or other wise of zero discharge concepts in palm oil mills in Malaysia.

VII. FINDINGS AND DISCUSSION

7.1 POME as a Difficult Waste from Palm Oil Mills

Although, different types of wastes are generated during processing of oil palm fresh bunches (FFB). According to Prasertan and Prasertan (1996), during processing of FFB in the palm oil mills, more than 70% (by weight) of the process FFB is usually left over as oil palm wastes. The wastes products from oil palm processing consists of oil palm trucks (OPT), oil palm fronds (OPF), empty fruit bunches (EFB), palm press fibers (PPF), palm kernel cake (PKC), shell, palm oil mill effluent (POME) and palm oil mill sludge (POMS) [5, 6].

Respondents were asked to provide their response on which of the wastes generated by them is more difficult to handle or manage. From the simple statistic percentage, 100% of the respondents claimed that POME is the most difficult waste to manage by the mill and these are some of the reasons given by the operators.

- The volume by weight of the POME generated per one ton of FFB is enormous.
- During POME treatment to reduce the level or strength of BOD and other parameters, other by products like biogas, sludge etc. are generated.

- It involved a lot of labor, required a lot of time, close monitoring and too expensive to achieve the required BOD level of 20ppm or less before final discharge.

Obviously, these are also some of the reasons why majority of palm oil mills discharged either partially or untreated POME into nearby rivers as reported several times happened at Kinabatangan and Tenaggang rivers all in Kota Kinabalu. In Mukah land District, Oya-Dalat land District and Miri-Bintulu all in Sarawak, various palm oil mills were fined between RM 18,000 (US $ 6000) to RM 25,000 (US $ 8333) and three months imprisonment each after the owners pleaded guilty to the charge framed against them under section 16 (1) of the Environmental Quality Act 1974 and punishable under section 16 (2) of the same act. The operators were found guilty of discharging POME into watercourse. All the liquid wastes discharged into the watercourse were found to contain substances in concentration exceeding the stipulated limits under regulation 12 (4) Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations, 1977.
According to the report by Borneo Post online, the mills were prosecuted by the Department Of Environment Officers. [45]

7.2 Methods or Technologies Palm Oil Mills used in treating POME

The cheapest way of discharging POME is to either disposed it on the land inform of land application or release it into the river untreated, since POME is a non-toxic oily waste. Nevertheless, discharging of POME into water bodies cause water depletion and results in aquatic pollution [46]. Over the last two decades, several treatment and disposal technologies have been successfully developed and used to treat POME [30]. They were all designed and constructed to meet a discharge limit of 100mg per liter BOD. These methods or technologies consist of conventional biological systems using aerobic and anaerobic and or facultative processes. If operated according to design criteria and maintained well, the process are able to treat POME to the discharge limit set by Malaysia Department OF Environment (DOE). However, type of method or technology currently implored by mills was reflected in the questionnaire responses. The percentage calculated from the survey responses provided 97% respondents claiming the use of ponding system of aerobic and anaerobic process in treating their POME.

Aerobic and anaerobic processes are biological treatment systems that rely solely on microorganisms to break down pollutants and they need proper maintenance and close monitoring. Microorganisms are very sensitive to change in their environment and hence, great care must be taken to maintain the condition in which they thrive. This requires the attention of skilled operators, and the commitment of management. Unfortunately, the palm oil industry still considers wastewater treatment a burden rather than as part of the production process, let alone a profit opportunity. Undoubtedly, this aspect has the lowest priority in the maintenance budget. As a result, according to [30] most palm oil mills are not always able to comply with the discharge limits. According to [31], anaerobic process is a suitable treatment method due to the organic characteristic of POME. Therefore, ponding system is the most conventional method for treating POME in Malaysia, [18, 47].

The pond system has been applied in Malaysia for POME treatment since 1982 and they are classified as waste stabilization pond [48]. [48], reported that more than 85% of palm oil mills exclusively use ponding systems due to their low cost. Ponding systems are easy operating systems but [48] and [49] argued that they have some disadvantages, such as occupying a vast amount of land mass, relatively long hydraulic retention time (HRT) of 45-60 days for effective performance, bad odor and difficulty in maintaining the liquor distribution and biogas production which results into harmful effect on the environment when allowed into atmosphere. However, production of biogas during anaerobic treatment of the POME has been considered as the main challenge being faced presently by the operators of the palm oil mills. Consequently, the management and utilization of this biogas as a source of renewable energy to control pollution aiming to achieve zero discharge concept is the focus of this study.

7.3 Knowledge of the Availability of the Current Advance POME Treatment Technologies by Palm Oil Mills Operators

Dozens of methods and technologies have been developed to treat and control POME pollution. This implied that, there is availability of various new advance POME treatment technologies that are ready to be acquire and use by palm oil mills. Nevertheless, the question is, does the palm oil mills operators have knowledge of the availability of these technologies? This study explored this question by asking the respondents if they have knowledge about these new advance technologies. A number of new technologies and methods were listed in the questionnaire and multiple responses were allowed. Overall, 86% of the respondents claimed to have knowledge of the new advance technologies and 2% of these respondents also claimed to be involved in research and development of new technology in collaboration with universities and research institution in and outside Malaysia. On the other hand, 14% of the respondents claimed not to have knowledge about availability of new advance POME treatment technologies.

There have been reports and review of literature on various new advance POME treatment technologies that has been tested and proven effective through a plot projects. Some are however still at the testing stage. A collaboration between Shanghai Jiao tong University and Malaysia's own Ronser Bio-Tech Sdn Bhd offered two proprietary systems called AnaEG and BioAX for evaluation at a pilot plant at Labu Negri Sembilan. The five tons per hour pilot plant at Labu is intended to demonstrate that is possible to achieve a zero emission of POME into environment. The plant is designed to be able to generate biogas at a rate of 150 cu. meters per hour, produce sludge that can be used as fertilizer, and produce wastewater that is good enough for boiler use. The first stage of the plant will see to the recovery of waste oil from POME, before the sludge is treated by the AnaEG or BioAX processes. The biogas that is produced will be captured for power generation by burning them in gas engines, while some solid high-potash fertilizer is also recovered. The final bits involve membrane separation, followed by ultrafiltration, and reverse osmosis, to produce clean water as shown in Fig 1.

Figure1. Pilot project of Ronser Bio-Tech's Zero Discharge POME treatment technology at Labu, Negri Sembilan

A new palm oil mill in Bintulu, Sarawak has also order a turnkey plant for effluent treatment and biogas recovery system. The advance technology is to be referred to as Membrane Bio Reactor (MBR), a wastewater treatment method that combines a membrane and bio treatment (Anaerobic), which the company has confirmed its performance based on the site pilot tests for two years.

Veolia Water Solutions and Technologies officially lunched and announced its Pomethane technology during 2012 POMREQ Conference in Malaysia. Veolia's Pomethane Technology offers affordable, greener solution to treat POME. Pomethane technology has already been implemented by several Southeast Asian companies, including Felda, Malaysia's largest crude palm oil producer. Pomethane, according to the company represents a best practice application for managing palm oil industrial waste through an anaerobic thermophilic digestion process. Some of the important benefits derivable from Pomethane Technology are;

- ✓ Technical solution that meets Clean Development Mechanism (CDM) requirement
- ✓ Economic efficiency
- ✓ In compliance with International Environmental Standards
- ✓ Environmental friendly and
- ✓ Renewable energy product

In addition, the anaerobic digestion of POME by use of thermophilic bacteria in Pomethane Technology provides a number of advantages compared to the conventional mesophilic bacteria;

- The retention time is significantly shorter at thermophilic operating conditions which results in a reduction of the digester tank size and thus capital cost and maintenance
- Thermophilic bacteria are capable of digesting more complex degradable substances, which may not be

degraded by mesophilic bacteria. This results in an increase of the biogas yield.

- At mesophilic temperature range fungi and viral may grow in the substrate thus causing potential health hazard from the effluent. Unwanted Microbiology will not survive in the thermophilic temperature range.
- The effluent from the secondary digester will run through a clarifier system.
- The effluent from the clarifier will be treated in the downstream wastewater treatment system.
- A part of the sludge will be recycled to the digester and the excess sludge can be composted after further decanting or taken straight to the plantation as fertilizer.

Finally, Pomethane Technology has the capacity to remove COD exceeding 90% and final effluent discharge of BOD < 20 PPM.

Other new advance POME treatment technology that has also been reported is Camco Southeast Asia. A regional clean energy company, planned to build a 2-megawatt biogas project in Malaysia that will make use of methane pollutants found in POME from palm oil mills. The US $ 4 million project is part of a 13 years “build-own-operate-transfer” agreement between Camco and the mill owner. Under the terms of agreement, the mill owner will provide adequate POME feedstock free for the entire duration of the contract. The biogas project will use anaerobic digestion technology for breaking down biodegradable material in the absence of oxygen.

In a related development, Alambumi Palm Oil Mill has also entered into collaboration agreement with Konzen Clean Energy Sdn Bhd to develop a CDM project at Alambumi Palm Oil Mill in Miri. Divided into two phases, the first phase would involve building up a closed anaerobic tank digester to capture methane gas costing around RM 7.5 million (US $ 2.5 million) and the second phase would be biogas utilization costing around RM 7 million. (US $ 2.3 million). However, this will be Konzen’s second biogas CDM project from palm oil mill effluent in Sarawak after Rinwood Pelita Palm Oil Mill in Mukah.

Professor Abdul Latif Ahmad of Universiti Technologi Malaysia (UTM) and his team invented a system, which he claimed could turn palm oil waste into drinking water. The invention is called the “Novel membrane-based treatment system which turns POME into crystal clear drinking water. According to inventor, the technology required four steps to treat the waste before it became clean enough to drink. The environment-friendly technology is set to reduce water pollution, as it will help ensure zero discharge of palm oil waste into rivers.

7.4 Willingness of the Palm Oil Mills to acquire and adopt the Current Advance POME Treatment Technology

There is no doubt that the current advance POME treatment technologies has been developed and found to be effective by various organizations as clearly mentioned earlier. The target was to help palm oil mills to achieve zero discharge concepts and to maximize the utilization of biogas generated during POME treatment as a source of renewable energy. On records, the technologies are also available in global biogas plants market. As stated earlier 86% of the palm oil mills captured in this study claimed to have knowledge of availability of new advance POME treatment technologies (PTT). However, the willingness of palm oil mills operators to acquire and adopt the new technology was reflected in the questionnaire responses. The respondents were asked to choose either “YES”, “NO” or “NOT SURE” to state their willingness of acquiring and adopting the new technology. 36% of the respondents choses “YES” indicating “Willingness”. While 41% of the respondents’ choses “NO” indicating “Unwillingness” and 23% of the respondents choses “NOT SURE” indicating neither YES or NO. The results of this survey revealed that despite the need for the palm oil mills to meet up with the new stringent condition of 20ppm BOD and imposed zero discharge requirements by Malaysia Department of Environment, many palm oil mills are not still willing and ready to acquire and adopt the new advance POME treatment technology.

This category of the palm oil mill operators clearly advanced the following reasons for their position. In some cases, millers claimed that utilization of biogas for power generation required a high initial capital to acquire a new plant. Many argued that the government call for millers to become green independent power producers (IPPs) is not practical. According to the millers, there are still no clear-cut biomass and biogas policy and sufficient incentives to convince them to go into such projects. The mill operators argued that until the government provide more attractive incentives for palm oil industry. This will encourage the millers to acquire the new advance POME treatment technology that enable them make full use of the biogas to first generate electricity for their mills and gradually selling its electricity to the national power grid where ever possible. One of such attractive incentive according to the millers is to increase the tariff on green energy from $ 0.21 per unit to between $ 0.29 and 0.40 per unit.

VIII. CONCLUSION

This paper has presented the key findings from the survey mailed to 86 palm oil mills located in Sarawak and Sabah in Malaysia. Although this is a pilot project, the survey results provide an overview of the position of the palm oil mills operators on current advance POME treatment technology in relation to achieving zero discharge concepts in their operations. The survey attempted to identify the key issues about the current advance POME treatment technologies in respect to feasibility of zero discharge concepts in palm oil mills in Malaysia.

The results shows that, although palm oil mills generate a lot of different types of wastes during processing of FFB, according to the operators and available literature POME is the most difficult and expensive waste to manage. This is because POME contains large quantity of pollutants that are harmful to the environment. Obviously, palm oil mills cannot meet up with the new discharge limits of 20ppm of BOD and zero emission in some sensitive areas using only conventional open ponding system. Therefore, there is need for paradigm shift from the conventional ponding system that is popular among palm oil mills in Malaysia to the current advance POME treatment technology. The new available technology has been proven effective to guaranty zero emission that improve environmental performance and ultimately curb the industry's environmental footprint. The results also found that majority of the operators generally have knowledge of the availability of the advance and more suitable POME treatment technologies. According to available records and reviewed literatures, some palm oil mills are already collaborating with different research institutions and manufacturing companies in acquiring the new POME treatment plants.

Although, the millers claimed they want to achieve zero emission to improve their environmental performance. The responses from the survey shows that majority of the millers are not willing to acquire and adopt the current technology. This was evident from the reasons they advanced as stated earlier.

Based on the survey, records, reports, and reviewed literatures, the finding of this pilot study can be summarized in the following points;

- Across the globe, current advance POME treatment technologies and or biogas plants are available for palm oil mills to acquire and adopt for clean production.
- Attractive incentives and supports, that were found to be a major factor that will attract the millers to embrace the new technology, are available at both national and international level.
- At the national level, the Malaysia government in her effort to promote green technology development in 2011, provided a found of up 500 million US dollar under the Green Technology Financing Scheme (GTFs). This is to support green technology development in Malaysia, which includes utilization of biomass, and biogas in palm oil industry. Ministry of Science, Technology and Innovation (MOSTI) and Ministry of Higher Education (MOHE) also financially support Malaysia's research and development sector. These ministries provide research grants to qualified institutions to support potential research projects that will promote the utilization of renewable energy sources.

The promotion of utilization of renewable energy sources available in Malaysia was implemented in 2011 under the Small Renewable Energy Program (SREP). Biogas generated from the treatment of POME was identified as one of these potential renewable energy sources. In addition to introduction of the fee-in-tariff (FiT) from US $ 0.09 KW/h onwards. Malaysia government has implemented the promotion of investment Act 1986 (The commissioner of Law Revision, 2006). This Act offers incentives to companies that generate energy from renewable resources that is then either sold to other companies or retained for self-consumption.

The incentives offered include the granting of Pioneer Status (PS), Investment Tax Allowance (ITA), Import Duty, and Sales tax Exemption (ID-STE). PS allows for income tax exemption on statutory income, whereas ITA offers tax allowances on qualified capital expenses. Any palm oil mill that produces biofuel or renewable energy is eligible for the incentive application to encourage the utilization of renewable energy sources. In a related development, commercial banks in Malaysia have also gone into Green Technology Financing (GTF) in view of the potential market for environmental business. Of the foreign commercial bank in Malaysia, Sumitonw Mitsui Banking Corp. of Japan has team up with the Federation of Malaysia Manufacturers (FMM) to provide RM 632 million (USD 200 million) financing for local manufacturers. It was first kind of financing from a commercial bank to be used on green initiatives such as renewable energy, recycling and waste management project. Other banks offering green financing include HSBC, Maybank, and Standard Chartered Bank.

However, during 6th World Islamic Economic Forum, Malaysia Prime Minister has also proposed the setting up of a Clean Energy Development Bank to boost Eco-sustainable efforts by developing countries of the organisation of the Islamic Conference.

- At the international level, the Clean Development Mechanism (CDM) under the Kyoto Protocol (UNFCCC,

1998) is a scheme to promote sustainable development. It introduces carbon credits through which developing countries can gain profit by trading certified emission reductions (CER), while developed countries can achieve their emission reduction targets by purchasing the tradable carbon credits. The palm oil industry is eligible to earn CER through biogas-methane capture released by POME.

More than five CDM projects from the palm oil industry were approved and issued at least 0.5Mt of CO_2 equivalent CER [50]. Recently, Rinwood Pelite palm oil mill in Miri and Alambumi palm oil mill in Mukah are among the few palm oil mills that have utilized this incentive from CDM project of carbon credits and other income generated from biogas utilization. With the worldwide trend in energy generation using RE, the availability of current advance POME treatment technology and attractive incentives at both national and international level. The prospect of zero discharge concepts and its feasibility in palm oil mills in Malaysia is certain.

Finally, more needs to be done in the aspects of incentives and support from Malaysia government. Green Investment Bank (GIB) for renewable energy, carbons capture and storage and energy efficiency measures recently launched in UK can be replicated and adopted by Malaysia government. More research and development that will result into less expensive technology should be encouraged. More collaboration with the stakeholders in palm oil industry. Awareness campaign through organizations like Round Table Sustainable Palm Oil (RSPO) will greatly influence the millers towards embracing the new advance POME treatment technology to achieve zero discharge concepts in Malaysia.

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