World Applied Sciences Journal 11 (1): 70-81, 2010
ISSN 1818-4952

Review of Current Palm Oil Mill Effluent (POME) Treatment Methods: Vermicomposting as a Sustainable Practice

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Abstract: The total oil palm cover has increased in the last few years, with a corresponding increase in palm oil production. As a result, palm oil waste which is a by-product of the milling process will also increase. The palm oil production process in mills consists of several unit operations. The processing of fresh fruit bunches of oil palm results in the generation of different types of residue. Among the waste generated, palm oil mill effluent (POME) is considered the most harmful waste for the environment if discharged untreated. Palm oil mill effluent is a thick brownish liquid that contains high solids, oil and grease, COD and BOD values. Several treatment technologies have been used for POME treatment, since the direct discharge of POME adversely affects the environment. Due to the presence of high total solids in POME, attempts have been made to convert this waste into valuable products such as feed stock and organic fertilizer. Although POME is organic in nature, it is difficult to decompose in natural conditions. Earthworms can digest the POME producing valuable products such as vermicompost. Vermicompost is a useful product rich in nutrients that can be used as fertilizer in oil palm plantations. This review discusses the various ongoing treatment techniques of POME. The effective treatment of POME using vermicomposting technique is suggested as a good alternative sustainable management practice of this waste.

Key words: Oil palm · Palm oil mill effluent · Palm oil mill waste · Vermicomposting

INTRODUCTION

Palm oil is one of the world's most rapidly expanding equatorial crops. Indonesia and Malaysia are the two largest oil palm producing countries and is rich with numerous endemic, forest-dwelling species. Malaysia has a tropical climate and is prosperous in natural resources. Oil palm currently occupies the largest acreage of farmed land in Malaysia [1]. The total oil palm acreage from 1970 to 2000 has increased from 320 to 3,338 hectares. However the agricultural acreage of rubber and coconut has decreased by the year 2000 (Table 1). In the year 2003 there were more than 3.79 million hectares of land under palm oil cultivation, occupying more than one-third of the total cultivated area and 11% of the total land area of Malaysia [2].

Palm oil, an edible oil, is derived from the fleshy mesocarp of the fruit of oil palm (*Elaeis gunineensis*). One hectare of oil palm produces 10 to 35 tonnes of fresh fruit bunches (FFB) per year [3].

Table 1: Malaysia - Agricultural Acreage 1970-2000 [1000 Hectares]

Crops	1970	1985	1990	1995	2000
Oil palm	320	1,482	2,030	2,540	3,338
Rubber	2,182	1,949	1837	1,679	1,590
Rice	533	655	681	673	692
Coconut	349	334	316	249	116

Source: (Arif and Tengku Mohd Ariff, 2001: 2)

The oil palm has a lifespan of over 200 years, while the economic life is about 20-25 years. The nursery period is 11-15 months for plants and first harvest is done after 32-38 months after planting. It takes 5-10 years for palm oil plant to reach peak yield. The yield is about 45-56 % of FFB and the fleshy mesocarp of the fruit is used to obtain oil. Yield of oil from the kernel is about 40-50% [4]. Both mesocarp and kernel of fruit produces about 17 t ha^{-1} $year^{-1}$ of oil [5]. From 5.8 tonnes of FFB about 1 tonne of crude palm oil (CPO) is produced [3].

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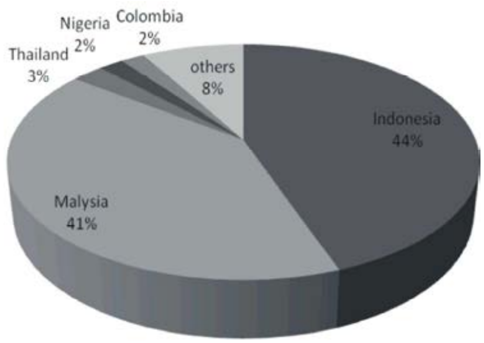

Country	Share (%)	Amount (Tones)
Indonesia	44	19000
Malaysia	41	17350
Thailand	3	1123
Nigeria	2	850
Colombia	2	832
Others	8	3556

Fig. 1: World palm oil production 2008 (M.P.O.B)

While the oil palm industry has been recognized for its contribution towards economic growth and rapid development, it has also contributed to environmental pollution due to the production of huge quantities of by-products from the oil extraction process. The waste products from oil palm processing consist of oil palm trunks (OPT), oil palm fronds (OPF), empty fruit bunches (EFB), palm pressed fibres (PPF) and palm kernel shells, less fibrous material such as palm kernel cake and liquid discharge palm oil mill effluent (POME) [3, 6].

According to Prasertsan and Prasertsan [7], during processing in the palm oil mill more than 70% (by weight) of the processed fresh fruit bunch (FFB) was left over as oil palm waste. According to Pleanjai *et al.* [8], fiber, shell, decanter cake and empty fruit bunch (EFB) accounts for 30, 6, 3 and 28.5% of the FFB respectively. According to Yacob *et al.* [9], 381 palm oil mills in Malaysia generated about 26.7 million tonnes of solid biomass and about 30 million tonnes of palm oil mill effluent (POME) in 2004. Discharging the effluents or by products on the lands may lead to pollution and might deteriote the surrounding environment. There is a need for a sound and efficient management system in the treatment of these by-products in a way that will help to conserve the environment and check the deterioration of air and river water quality. Treatment of POME is essential to avoid environmental pollution. There is a growing interest in composting as well as vermicomposting process. Since wastes from oil palm mill are biological in nature, composting as well as vermicomposting can be a good sustainable waste management option of this waste. Soil macro organism, such as earthworms have considerable potential to increase the decomposition process, consequently it reduces the waste volume and resulted into the value added product [10, 11]. The present review discusses the various aspects of POME treatment methods and the potential of vermicomposting as an alternative sustainable management practice of this waste.

Malaysian Oil Palm Industry: Frenchman Henri Fauconnier and his associate Hallet, is attributed for the development of the oil palm industry in Malaysia. The first commercial oil palm plantation was established by Fauconnier at Tennamaram Estate, to replace an unsuccessful planting of coffee bushes [12]. Oil palm, Elaeis *guineensis*, belonging to the Palmae family, is the most productive oil producing plant in the world. The oil palm contains a high nutrient which mainly depends on the yield potential determined by the genetic make-up of the planting material and yield limit set by climatic factor such as water, effective sunshine and temperature [13]. Nigeria was overtaken by Malaysia as world's leading producer and exporter of palm oil in 1966 and 1971 respectively [14, 15]. According to Malaysian palm oil board [16] the global production of palm oil and the plantation area has been increased. Malaysia contributes 41% of the world production (Figure 1).

Palm Oil Production Process: Several unit operations are involved in order to extract palm oil after the fresh fruit bunches (FFB) are transported to the palm oil mills. Two types of oils are produced from oil palm, one is the palm oil from the fibrous mesocarp and another is lauric oil produced from the palm kernel. The main stages of palm oil processing are shown in Figure 2.

Sterilization: The first stage in extraction of crude palm oil is sterilization. Fresh fruit bunches (FFB) are sterilized inside autoclave using steam at about 140°C for a period of 75-90 minutes. The purpose of sterilization process is to deactivate hydrolytic enzymes responsible for the breakdown of oil to free fatty acids and to loosen the fruits from bunches. The mucilage will be coagulated due to breaking of oil cells. One of the major sources of waste water in this step is constituted by the steam condensate coming out of the sterilizer [17].

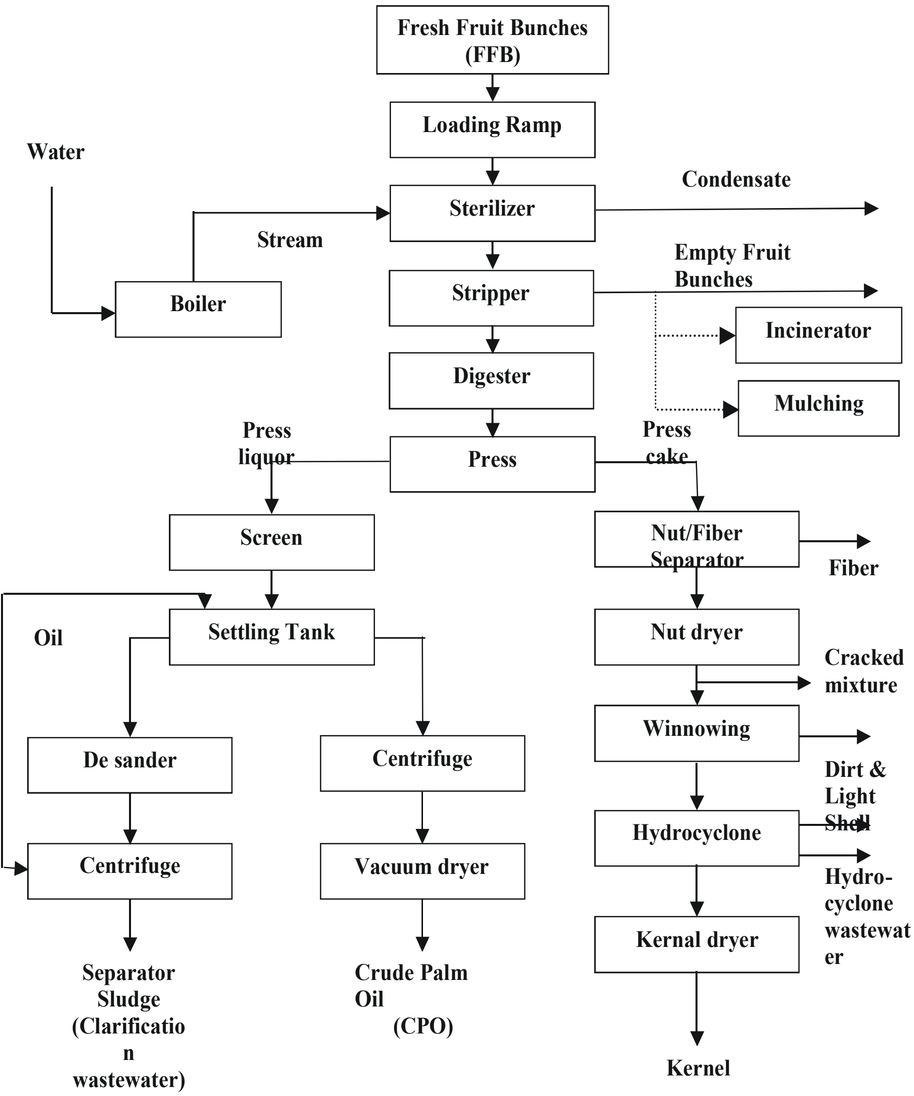

Fig. 2: Process involved in milling of oil palm

Stripping or Threshing: After sterilization process fruits are stripped and separated from the bunch in a rotary drum stripper. The fruits are lifted and dropped through the stripper in order to be knocked out of the bunches. The detached fruits fall through the space between the bars on the stripper and collected in a bucket conveyor and discharged into a digester. The resultant waste from this step is empty fruit bunches (EFB).

Digestion: Digestion involves the mashing up the fruits under steam heated condition in a digester. The digester is a vertical cylindrical vessel fitted with rotating arms. The action of mashing the fruits under heating is to break the mesocarp oil-bearing cells. Hot water is added in digester to enhance the flow of the oils. No residue occurs in this step.

Palm Oil Extraction: Homogeneous oil mash coming out from the digester is passed through a screw press followed by a vibrating screen, a hydrocyclone and decanters to remove the fine solids and water. The oil is purified by using the centrifuge and vacuum drier before sending it to the storage tank. The storage will maintain the temperature to 60°C with steam coil heating. The crude oil slurry is then fed into a clarification system for oil separation and purification. The fiber and nuts are separated by passing through the depericarper [17]. The crude palm oil (CPO) contains a mixture of palm oil (35-45%), water (45-55%) and fibrous materials in different portions. After passing the CPO from the screw presser it will be pumped to a horizontal or vertical clarification tank to skim the oil from top of the clarification tank. The crude palm oil is then passed through a high speed

Table 2: Characteristic of raw POME and the regulatory discharge limits

Parameters	Value[a]	Regulatory discharge limits[b]
Temperature (°C)	80-90	45
pH	4.7	5.0-9.0
Biochemical Oxygen Demand BOD3; 3days at 30 °C	25,000	100(50)
Chemical Oxygen Demand	50,000	-
Total Solids (T.S)	40,500	-
Total Suspended Solids (T.S.S)	18,000	400
Total Volatile Solids (T.V.S)	34,000	-
Oil and Grease (O&G)	4,000	50
Ammonia-Nitrate (NH_3-N)	35	150
Total Kjeldahl nitrogen (TKN)	750	200

*All values, except pH and temperature, are expressed in mgL-1; POME= Palm oil mill effluent

Sources: [a]Ma (2000), [b]Ahmad and others (2003)

centrifuge and a vacuum dryer before being sent to storage tanks. The major wastes of this stage are decanter wastewater and decanter cake.

Generation of Waste in Palm Oil Mills: Huge quantities of waste are produced in the palm oil mill industry. The process of oil extraction results in generation of liquid waste commonly named as palm oil mill effluent (POME). Palm oil mill effluent is generated mainly from oil extraction, washing and cleaning processes in the mill and these contains cellulosic material, fat, oil and grease etc [18]. Palm oil mill effluent also contains substantial quantities of solids, both suspended solids and total dissolved solids in the range of 18,000 mg L^{-1} and 40,000 mg L^{-1} respectively (Table 2). These solids are commonly named palm oil mill sludges (POMS). The solid waste that are produced in the process of extraction are the leaves, trunk, decanter cake, empty fruit bunches, seed shells and fibre from the mesocarp.

Palm Oil Mill Effluent (POME): Characteristics of palm oil mill effluent depend on the quality of the raw material and palm oil production processes in palm oil mills. The extraction of crude palm oil from FFB requires huge amounts of water. It has been estimated that 5- 7.5 tonnes of water is required for producing 1 tonne of crude palm oil and more than 50% of the water ends up as palm oil mill effluent (POME) [19, 20, 21]. Sethupathi [22] has categorized three major processing operations responsible for producing the POME. Sterilization of FFB, clarification of the extracted CPO, hydrocyclone separation of cracked mixture of kernel and shell hydrocyclone contributes about 36, 60 and 4% of POME respectively in the mills. Lorestani [23] estimated that in Malaysia about 53 million m^3 POME is being produced every year based on palm oil production in 2005 (14.8 million tonnes). Yacob *et al.* [24] estimated that about 0.5- 0.75 tonnes of POME will be discharged from mill for every tonne of fresh fruit bunch.

Wastewater composition depends mainly on the season, raw matter quality and the particular operations being conducted at any given time. Typically, palm oil mill wastewater is low in pH because of the organic acids produced in the fermentation process, ranging about 4-5. It also contains large amounts of total solids (40,500 mg l^{-1}), oil and grease (4000 mg l^{-1}) [25] (Ma, 2000). Wastewater includes dissolved constituents such as high concentration of protein, carbohydrate, nitrogenous compounds, lipids and minerals, which may be converted into useful materials using microbial processes. The effluents from palm oil mill can cause considerable environmental problems, if discharged untreated [3, 26]. Therefore, the challenge of converting POME into an environmental friendly waste requires an efficient treatment and effective disposal technique.

Regulatory Standards for Palm Oil Mill Effluent: Malaysian experiences in effluent control in the palm oil industry demonstrate that a set of well designed environmental policies can be very effective in controlling industrial pollution in a developing country. The Environmental Quality (prescribed Premises) (Crude Palm Oil) Regulations 1977, promulgated under the enabling powers of Section 51 of the EQA, are the governing regulations and contain the effluent discharge standards. Other regulatory requirements are to be imposed on individual palm oil mills through conditions of license according to Environmental Quality Act 1974 [27]. The effluent discharge standards ordinarily applicable to crude palm oil mills are presented in Table 3.

Table 3: Effluent discharge standards for crude palm oil mills (Environmental Quality Act 1974, 2005)

Parameter	Unit	Parameter Units (second schedule)	Remarks
Biochemical Oxygen Demand BOD; 3days- 30°C	mg/l	100	
Chemical Oxygen Demand (COD)	mg/l	*	
Total Solids	mg/l	*	
Suspended Solids	mg/l	400	
Oil and Grease	mg/l	50	
Ammoniacal Nitrogen	mg/l	150	Value of filtered sample
Total Nitrogen	mg/l	200	Value of filtered sample
pH	-	5-9	
Temperature	°C	45	

* No discharge standard after 1984

Source: (Pierzynski 2005)

Table 4: Characteristics of individual waste water streams (Industrial Process and The Environment 1999)

Parameters	Sterilizer condensate	Oil clarification wastewater	Hydrocyclone 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

Malaysia is identified as the country that produces the largest pollution load in the river [29]. Due to this fact, the palm oil industry faces the challenge of balancing the environmental protection, its economic viability and sustainable development. There is an urgent necessity to find an approach to preserve the environment while keeping the economy growing.

Characteristics of Palm Oil Mill Effluent (POME): Fresh POME is a hot, acidic (pH between 4 and 5), brownish colloidal suspension containing high concentrations of organic matter, high amounts of total solids (40,500 mg L^{-1}), oil and grease (4,000 mg L^{-1}), COD (50,000 mg L^{-1}) and BOD (25,000 mg L^{-1}) [25] (Ma, 2000). The characteristic of typical POME is given in Table 2. The typical characteristic of the individual wastewater streams coming out of palm oil mill from the three principal source of generation is given in Table 4. According to Vairappan and Yen [29], 66.8 million tonnes of POME was generated in year 2005. The raw or partially treated POME has an extremely high content of degradable organic matter. As no chemicals were added during the oil extraction process, POME is considered as non toxic, but it is identified as a major source of aquatic pollution by depleting dissolved oxygen when discharged untreated into the water bodies [30] (Khalid and Wan Mustafa, 1992). However it also contains appreciable amounts of N, P, K, Mg and Ca [31, 32], 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.

Muhrizal, (2006) reported that POME contains high content of Al as compared to chicken manure and composted sawdust. According to Habib *et al.* [31] toxic metals, such as Pb, can also be focused in POME, but their concentrations are usually below sublethal levels (> 17.5 µg /g) [33]. According to James *et al.* [33], Pb is found in POME as a result of contamination from plastic and metal pipes, tanks and containers where Pb is widely used in paints and glazing materials.

Palm Oil Mill Effluent Treatment Technologies: Land application of palm oil mill effluent (POME) is one of the disposal alternatives. Discharging the POME on the land results in clogging and water logging of the soil and kills the vegetation on contact. However, Wood *et al.* [34] reported that, these problems could be overcome by the controlled application of small quantities of POME at a time. The cheapest way of discharging of POME is to release it into the river, since POME is a non toxic oily waste. But discharge of effluent into water bodies cause water depletion and results in aquatic pollution [28]. Therefore, these problems makes it necessary to study on different types of treatments. Several researchers have studied the various aspects of palm oil mill effluent treatment [35-39].

Physical pretreatment of POME includes stages such as screening, sedimentation and oil removal prior to the secondary treatment in biological treatment system. According to Hojjat and Salleh [40] the combination of two processes of acidification pond and flocculation treatment is a developed pretreatment process. Hojjat and Salleh [40] showed that both centrifugation and coagulation gave different pretreatment quality which was reported to be better than that of pretreatment by filtration method. Apart from this process different chemicals are used in flocculation such as alum, aluminium chlorohydrate, aluminium sulfate etc. There are some natural products such as chitosan (poly D-glucosamine) that have been used in flocculation. Chitosan is a natural organic polyelectrolyte of high molecular weight and charge density; obtained from deacetylation of chitin. As the suspended solids in POME are mainly associated with its organic matter, therefore chitosan can effectively remove most of the colloidal and suspended organic matter contents, but is less efficient in removing of dissolved organic matter [41]. Solvent extraction method was used by Hameed *et al.* [42] for removal of residual oil from POME as a pretreatment process. Hameed *et al.* [42] reported that the percentage extraction of oil from POME increased with the increase of mixing time, solvent/feed ratio and mixing rate for all solvents.

According to Perez *et al.* [43], 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 [30, 44]. The pond systems have been applied in Malaysia for POME treatment since 1982 and they are classified as waste stabilization pond [45]. More than 85% of palm oil mills exclusively use ponding systems due to their low costs. Ponding systems are easy operating systems but they have some disadvantages such as occupying a vast amount of land mass, relatively long hydraulic retention time (HRT) of 45-60 d for the effective performance, bad odor and difficulty in maintaining the liquor distribution and biogas collection which results harmful effect on the environment [45-47].

There is a possibility of improvement of POME treatment by other processes such as aerobic and anaerobic digestions, physicochemical treatments and membrane filtration [48]. The organic substance of POME is generally biodegradable; therefore treatment by biodegradable process could be suitable, which are based on anaerobic, aerobic and facultative processes [22]. Anaerobic process or biological treatment has considerable advantages over other processes such as less energy demands, minimum sludge formation, no unpleasant odor and production of methane due to efficient break down of organic substances by anaerobic bacteria [49]. According to Link [50] the anaerobic digestion process has great potential for rapid disintegration of organic matter to generate biogas that can be used in electricity generation and save fossil energy.

However, such biological practices are only applicable in the palm oil mills which acquire large area of lands [51]. According to Ahmad *et al.* [52] the treatment process that is based mainly on biological treatment is quite inefficient in treatment of POME, which may lead to several environmental pollution issues. This is largely due to the high BOD load and low pH of POME, together with the colloidal nature of the suspended solids, which renders POME treatments by environmental methods difficult [53, 54].

Palm Oil Mill Sludge (POMS) Characteristics: As it has been described earlier in section 4, palm oil mill effluent (POME) consists of suspended solids and dissolves solids which are left after POME treatment, commonly named as palm oil mill sludge (POMS). Therefore due to large quantity of POME production each year, the amount of POMS increases respectively. Palm oil mill sludge (POMS) has a higher nutrient value than the slurry [55]. It has high amount of moisture content, with the pH of 8.4 and enriched with nutrients. It has been shown in Table 5, POMS contains 3.6, 0.9, 2.1 mg L^{-1} of total nitrogen, phosphorus and potassium respectively. These sludges results in bad odors and is considered as a source of surface and ground pollution. Therefore, industries are looking for cost effective sustainable technologies for disposal of industrial sludges.

Table 5: Physicochemical analysis of raw POMS and empty Fruit Bunch

Parameters	[a]POMS (Average)	[b]Empty fruit bunch
Moisture content %	85.0	60
pH	8.4	6.7 ± 0.2
Organic matter	60.0	-
Total Organic carbon (TOC)	33.0	-
Total Nitrogen (TN)	3.6	58.9(%)
Phosphorus (as P_2O_5)	0.9	0.6± 0.1 (%)
Potassium (as K_2O)	2.1	2.4 ± 0.4 (%)

Sources: aYaser and others (2007), bBaharuddin and others (2009), All values are in mgL^{-1} except pH

Palm Oil Mill Sludge (POMS) Management: The oil palm mills generate many by-products and wastes besides the liquid wastes that have been mentioned, that may have a significant impact on environment if they are not properly dealt with. Among these by-products palm oil mill sludges (POMS) as result of POME treatment plays crucial impact on the environment, which makes it necessary to find a proper technology for mitigating these wastes.

According to Chooi [56], palm oil mill sludge (POMS) can be dried and used as a fertilizer as it contains high nutrient value. Drying is mostly done in open ponds, but during the rainy seasons this process becomes difficult due to slow rate of drying and over flow problem. Composting as well as vermicomposting technology can be used in POMS management.

Composting Technology: Composting, a microbial technology, is frequently used in stabilization of organic waste either from industrial origin or domestic waste. During the composting process, aerobic microorganisms decompose the substrate, therefore, most of the biodegradable organic compounds are broken down and a portion of remaining organic material is converted into humic acid like substances, with the production of chemically stabilized composted material [57, 58]. Due to rapid activation of microbes around the root systems the oxygen concentration decreases as a result of partially decomposed or unstable compost. In addition, chemically unstable compost is phyto-toxic due to production of ammonia, ethylene oxide and organic acids [59, 60]. Therefore, estimation of compost stability prior to its use is essential for recycling of organic waste in agriculture soils [61]. The organic residues recycling in soil can mitigate environmental hazards resulting from intensive agriculture [62]. Composting is being advised since it can reduce the volume/weight of sludge [63].

Several modification have been made for improving the composting process, increasing the degradation rate and quality of the final compost, such as the addition of biodegradable wastes to reach the optimum C/N ratio of about 30 [64], this is commonly known as co-composting.

Baharuddin *et al.* [65] carried out co-composting process using partially treated POME with empty fruit bunches (EFB). The partially treated POME from anaerobic pond was sprayed onto the shredded EFB throughout the treatment. The compost obtained was reported to have considerable amount of calcium, magnesium, phosphorus, potassium and other micro nutrients, therefore it might be suitable to be used as fertilizer for plantation purpose [65]. Saw mills and furniture industries usually burns the saw dusts generated at the mills which results in air pollution problems. Mixing saw dusts with POMS can mitigate the air pollution and improve the efficiency of composting process [66]. Yaser *et al.* [67] carried out the co-composting process by using the palm oil mill sludge (POMS) with sawdust. The sludges were collected from anaerobic digestion pond and recycled compost came from kitchen waste was added to facilitate the composting process; also the saw dust was collected from the furniture factories. Nutrient content in POMS compost is comparable with other industrial sludge compost.

Yaser *et al.* [67] reported that final compost showed some fertilizer value, but needed to be adjusted to obtain an ideal substrate. As a result, compost of palm oil mill-saw dust mixed with sand was found to improve the growth of *Cymbopogun citratus* [67]. Therefore, composting can be a suitable method for converting palm oil mill sludge into compost that can be used as a fertilizer for plantation purposes.

Vermicomposting Technique: Vermicomposting is described as composting or natural conversion of biodegradable waste into high quality fertilizer with the help of earthworms. Vermicomposting is the process in which earthworms are used to convert organic materials into humus-like material known as vermicompost or earthworm compost. Through vermicomposting process physical, chemical and biological reactions take place, resulting changes in the organic matter. The resultant product (vermicast) is much more fragmented, porous and microbially active [68, 69]. In contrast to traditional microbial waste treatment, vermicomposting process results in bioconversion of the organic wastes into two useful products: the earthworm biomass and

Table 6: Nutrient composition of vermicompost and garden compost

Nutrient element	Vermicompost %	Garden compost %
Organic carbon	9.8-13.4	12.2
Nitrogen	0.51-1.61	0.8
Phosphorus	0.19-1.02	0.38
Potassium	0.15-0.79	0.48
Calcium	1.18-7.61	2.27
Magnesium	0.0093-0.568	0.57
Sodium	0.058-0.158	<0.01
Zinc	0.0042-0.110	0.0012
Copper	0.0026-0.0048	0.0017
Iron	0.2050-1.3313	1.1690
Manganese	0.013-0.2038	0.0414

Source: Nagavallemma and others (2004)

the vermicompost. Earthworm biomass can further be processed into proteins as a source of animal feeds [70, 71]. The latter product (vermicompost/casting) is considered as homogenous, has reduced levels of contaminants and tends to hold more nutrients. During the vermicomposting process, important plant nutrients such as nitrogen, phosphorus, potassium, etc. present in the waste are converted into much soluble and available to plants [72]. Nagavallemma *et al.* [73] have reported that the nutrient composition of vermicompost may increase the plant nutrients as compared to the simple composting (Table 6).

Although various physical, chemical and microbial methods of disposal of organic solid waste are currently in use, these methods have some disadvantages and involve high cost. In this regard 'Vermicomposting' has been reported to be a viable, cost effective technique for the efficient management of the organic soil waste [74, 75]. Several researches have demonstrated the ability of earthworms to obtain the biodegradable part of the municipal solid waste as well as industrial wastes [76, 77].

Butt [78] reported solid paper mill sludge as a suitable feed for *Lumbricus terrestris* under laboratory conditions. The sludge of paper mill did not show adverse effect on the earthworms, although worm growth rate was poor. Elvira *et al.* [79] carried out the study on the efficiency of *Eisenia anderi* in bioconverting paper-pulp mill sludge mixed with primary sewage sludge. Elvira *et al.* [79] reported that, the mixture of 3:1 ratio found to be suitable medium for optimum growth and reproduction of earthworms. The Epigeic earthworm species live in organic wastes and requires high moisture content, adequate organic material content and dark conditions for proper growth and development [80-82]. Hartenstein and Hartenstein [70] carried out the laboratory work study on vermicomposting of activated sludge and reported that approximately 1.0g worm could ingest 4.0g of activated sludge in 5 days. In order to make use of earthworms successful in vermicomposting, its survival, growth and fecundity in different wastes should be known [83].

As oil palm is a highly nutrient demanding crop, using waste from palm oil mill as fertilizer supplement in place of inorganic nutrients is an environmentally friendly option. Sabrina *et al.* [77] carried out a study on the vermicomposting of oil palm empty fruit bunches (EFB) and its potential in supplying of nutrients for crop growth. Sabrina *et al.* [77] placed 100g of air dried (< 2mm) ground organic residue, empty fruit bunches (EFB) and oil palm frond into the plastic box (20 cm× 7.5 cm× 15 cm) and cover it with pierced lids for aeration. About 4.5g of dried cow dung was added to each box as a food supplement for the earthworms and accelerating the decomposition process. The weight, cocoon production and mortality of earthworms were monitored monthly. The ratios of stocking density treatment were 1:15, 1:10, 1:7.5, 1:6 and 1:5 of earthworm / media. The effect of stocking density at the ratio of 1:10 and 1:15 (earthworm /media) at the fifth week showed the higher growth response of earthworms. Meanwhile the highest earthworm density showed a higher concentration of total nitrogen (TN), K and Ca in vermicompost as its final product. Therefore it could be concluded that the vermicomposting process improved the quality of the compost materials with respect to nutrient content [77].

CONCLUSION

Oil palm is the major plantation in Malaysia and Indonesia. As the world palm oil demand is increasing generation of waste is also increasing. If they are discharged untreated, they may cause serious problem and deteriorates the environment in contact. Thus environmental management through waste management should be given main emphasis. There is a need of appropriate waste minimization or recycling technology which should be easy to operate and cost effective. As palm oil mill effluent is non toxic and considered as a good source of organic nutrients land application of POME can be a suitable waste management option. Use of composting as well as vermicomposting technology is also an efficient waste management option. Vermicast are nutrient rich and devoid of pathogens. Using vermicompost/ compost in agriculture will help in recycling the plant nutrients and help the soil from soil degradation. By reducing the load on inorganic fertilizer it will also boost the economy. Moreover using vermicompost / compost as organic amendment will help in maintaining the sustainability of ecosystem.

ACKNOWLEDGEMENT

The study was funded through Universiti Sains Malaysia (USM) short-term grant number 304/PTEKIND/ 6310003. The authors acknowledge USM for providing research facilities.

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