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THE POTENTIAL OF TREATED PALM OIL MILL EFFLUENT (POME) SLUDGE AS AN ORGANIC FERTILIZER

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ABSTRACT

Palm oil mill contributed a significant benefit to agro-based industry and social-economic for Malaysia. Palm oil mill effluent (POME) is considered as a polluted wastewater and the treated POME sludge was produced from the open treatment ponds. The objective of this study was to determine the physicochemical characteristics of treated POME sludge and its potential as an organic fertilizer. It was collected from the dumping ponds in Felda Jengka 8, palm oil mill. Physicochemical characteristics, sampling and preparation of samples were analyzed according to the standard method of soil and the wastewater. The samples were collected after one and six month of age with different depths (one, two and three meters). The statistical analysis revealed that the depth was not significant on the physicochemical characteristics. The characteristics of the treated POME sludge was measures using CHNS-O, C/N ratio, solid analysis, heavy metal, macro- and micronutrient, moisture content, and pH. However, the elements of oxygen, iron and pH were shown an interaction effects with time. In conclusion, the treated POME sludge has shown significant effect and the potential used as an organic fertilizer. Indeed, further studies on crops response are being conducted to prove the findings.

Keywords: dumping pond; organic fertilizer; treated POME sludge

INTRODUCTION

The oil palm industry produces a wide waste from oil extraction and processing (Singh *et al*., 2010). It creates a large quantity of discharge effluent into the river (Nutongkaew *et al*., 2014, Prasertsan, 1996). Currently, it is also generating a large amount of waste including sludge. Palm oil mill sludge contains high moisture content and nutrient (Nutongkaew *et al*., 2014; Yaser *et al*., 2007). In general, millions tonnes of sludge were pumping into the dumping ponds. However, the practices of sludge treatment were not specified and the mills can be operated with the most suitable waste treatment which is more cost effective and its availability in the sector. In practices, it has been observed that the palm oil miller is simple, low cost of wastewater treatment including POME sludge especially in the open pond system. The attractiveness of the treatment systems is due to their simplicity in the design which is typically based on empirical design. In theory, POME sludge can produce a high amount of organic substances which are suitable for organic fertilizer in the plantation. This study investigated the substrate of potential elements from treated POME sludge and its affect towards the environment and health. Therefore, it is vital to investigate the type of elements released from the treated POME sludge into the dumping ponds.

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MATERIALS AND METHODS

This study was carried out at palm oil mill in Felda Jengka 8, Bandar Tun Abdul Razak Jengka, Pahang, Malaysia. The samples of treated POME sludge were obtained from the dumping ponds from the palm oil mill. The purpose of the dumping ponds is as the palm oil mill maintenance operation for POME sludge treatment. The maintenance is done regularly two times in a year.

The treated POME sludge used in this study was taken from one and six months old of age at one, two and three meters depth of the dumping pond. The sampling and preparation of treated POME sludge was carried out according to the standard methods for examination of wastewater (APHA, 2005) and soil sampling method (CSSS, 2007). The determination of physicochemical characteristic was carried out according to the recommended standard procedures.

The statistical analysis was to determine the significant effect of the data collected using SPSS ver. 20 software. The results of the physico-chemical characteristics were evaluated by analysis of variance (ANOVA) and the interaction effects between the time (month) and depth (dumping pond) were also being analyzed. Correlation analysis was used to evaluate the relationship effects of time and depth with physicochemical characteristic (CNHO analysis, C/N ratio, solid analysis, heavy metal, nutrient, moisture content, pH, morphology characteristics and microorganism).

RESULTS AND DISCUSSION

Characteristics of Treated POME Sludge

Figure 1 shows the characteristic of treated POME sludge with different color and texture during the collecting of the samples. The treated POME sludge was shown blackish in color, soft texture and odor smell (Figure 1).

Thus, the treated POME sludge materials provided better moisture content, pH value, C, N, O, C/N ration, total solid and volatile solid which was suitable for microorganism growth and degraded the organic fertilizer materials (Table 1).

Figure 1. The characteristic of treated POME sludge (A) The physical characteristic treated POME sludge in the dumping pond; (B) The treated POME sludge at the dumping pond

Comparison between final compost (Wan Razali *et al*., 2012), POME anaerobic sludge (Baharuddin et al., 2010) and treated POME sludge was done for the physicochemical characteristics (heavy metal and nutrient) and the result showed there was insignificant different (Table 2).

Based on the results shown in Table 2, the treated POME sludge was identified suitable and highly correlated with the standard from WHO for human consumption and safety in term of heavy metal elements and microorganism. Moreover, weather condition and age of POME sludge in the dumping pond may also contribute to the variation of its characteristics.

CHNS-O Elements

In the analysis of variance (ANOVA), the interaction effects between time and depth from the elements of Carbon (C), Nitrogen (N) and Oxygen (O) is shown in Table 3. The main factors of time (month) was found to affect Carbon (C) and Nitrogen (N) significantly at $p<0.01$. Meanwhile, Oxygen (O) was recorded significantly different at 7.15*, respectively. However, other factors showed no significant interaction between time (month) and depth for all the elements.

Table 1. Characteristic of final compost, POME anaerobic sludge and treated POME sludge

Parameters	Final compost (Wan Razali *et al.*, 2012)	POME anaerobic sludge (Baharuddin *et al.*, 2010)	Treated POME sludge
Carbon (%)	38.5	37.5	25.53
Nitrogen (%)	2.7	4.7	4.21
C/N ratio	13.8	6.7	6.35
Moisture content (%)	49.3	95.0	68.46
pH value	7.5	7.41	7.40
Total solid (%)	-	-	32.40
Volatile solid (%)	-	-	89.43

Table 2. Comparison between nutrients and heavy metal elements in the final compost, treated POME sludge and WHO standard

	POME anaerobic sludge (Baharuddin *et al.*, 2010)	Treated POME sludge	WHO-ML Standard
Composition of heavy metal elements			
Copper (mg kg^{-1})	70.40 ± 21.60	45.05 ± 2.87	75.00
Chromium (mg kg^{-1})	9.30 ± 0.20	27.86 ± 0.55	150.00
Cadmium (mg kg^{-1})	n.d	0.41 ± 0.01	1.90
Zinc (mg kg^{-1})	151.00 ± 14.50	130.11 ± 3.49	140.00
Plumbum (mg kg^{-1})	0.5± 0.60	0.38 ± 0.10	0.30
Nickel (mg kg^{-1})	14.0 + 2.2	10.77 ± 0.15	67.00
Manganese (mg kg^{-1})	495.24± 48.3	422.56 ± 12.04	500.00
Composition of nutrient elements			
Boron (mg kg^{-1})	n.d	n.d	-
Ferrum (%)	1.09± 0.40	2.24 ± 0.02	-
Potassium (%)	5.16± 2.20	0.03 ± 0.01	-
Calcium (%)	2.55± 0.10	1.67 ± 0.04	-
Magnesium (%)	1.41± 0.20	0.55 ± 0.02	-
Phosphorus (%)	1.25± 0.10	0.08 ± 0.01	-
Sulphur (%)	1.21± 0.30	0.30 ± 0.01	-

Remarks: WHO-ML; Codex Alimentarius Commission (FAO/WHO). Food additives and contaminants. Joint FAO/WHO Food

Table 3. The summary of the ANOVA on CNO elements, C/N ratio, solid analysis, moisture content, pH value heavy metal and nutrient

SOV	Df	C (%)	N (%)	O (%)	C/N Ratio	MC (%)	pH	Total solid (%)	Volatile solid (%)	Cr (mg kg^{-1})
Time (T)	1	8.50**	10.50**	7.15*	1.98ns	4.30*	7.08*	4.30*	0.01ns	0.44ns
Depth (Dp)	2	0.05ns	0.67ns	0.02ns	1.48ns	0.51ns	2.03ns	0.51ns	0.28ns	0.04ns
T x Dp	2	0.10ns	0.17ns	0.03ns	0.12ns	0.31ns	0.71ns	0.31ns	0.70ns	0.01ns

Table 3. *(continued)*

SOV	Df	Cd (mg kg^{-1})	Zn (mg kg^{-1})	Pb (mg kg^{-1})	Fe (%)	K (%)	Ca (%)	Mg (%)	P (%)
Time (T)	1	4.84*	1.74ns	2.28ns	0.01ns	2.77ns	2.05ns	4.41ns	3.19ns
Depth (Dp)	2	1.50ns	3.59*	0.04ns	3.01ns	1.46ns	2.65ns	3.35ns	0.36ns
T x Dp	2	0.14ns	0.03ns	0.06ns	0.77ns	1.52ns	1.10ns	1.65ns	0.75ns

Remarks: SOV = source of variance; Df = degree of freedom; ns = not significant at p>0.05; * = significant at p>0.05; ** = highly significant at p<0.01

Table 4. Correlation coefficient on the effects of time and depth of the CNO elements, C/N ratio, heavy metal, nutrient, moisture content and pH value of treated POME sludge

	C (%)	N (%)	O (%)	C/N ratio	MC (%)	pH	TS (%)	VS (%)
Time	-0.509**	-0.539**	0.478**	0.26ns	-0.379*	0.440*	0.38*	-0.02ns
Depth	-0.02ns	-0.18ns	-0.03ns	0.31ns	-0.034ns	0.310ns	0.03ns	-0.03ns

Table 4. *(continued)*

	Cr (mg kg^{-1})	Cd (mg kg^{-1})	Zn (mg kg^{-1})	Pb (mg kg^{-1})	Fe (%)	K (%)	Ca (%)	Mg (%)	P (%)
Time	-0.133ns	0.148ns	-0.230ns	-0.293ns	0.48*	-0.48*	0.13ns	-0.41*	-0.04ns
Depth	0.012ns	-0.110ns	0.207ns	0.053ns	0.02ns	-0.19ns	0.01ns	-0.08ns	-0.10ns

Remarks: ns = no significant correlation; * = significant at p>0.05; ** = highly significant at p>0.01

The correlation analysis (Table 4) further revealed that the Oxygen (O) showed positive correlation with increasing time (month) (r = 0.478**, respectively). However, the Carbon (C) and Nitrogen (N) revealed a high negative correlation with time (month) (r = -0.509** and -0.539**). According to Gujer (1980), the sludge contents an organic material which related to the production of oxygen. This was due to the fact that anaerobic digestion was a biochemical processes that could convert a variety of organic matter naturally by microorganisms under oxygen to produce a gaseous composed of methane (Botheju and Bakke, 2011). According to Wan Razali *et al*., (2012), the content of N is shown significant increased while C decreased due to decomposition of the organic material. In addition, according to Wan Razali *et al*. (2012), N loss mostly happened by volatilization, however it can be reduced by maintaining moisture content range from 50-60% (Hubbe *at al*., 2010) and increases in pH during the thermophilic phase (Tumuhairwe *et al*., 2009).

C/N Ratio

However, based on the summary of the ANOVA shows that there is no significant different of C/N ratio with the different depth of the dumping pond (Table 3) but only the effect of time shows a significant difference. According to Wan Razali *et al*., (2012), C/N ratio decreased over time due to the decomposition activity. This phenomenon positively related to the content of C and N throughout the composting period (Bernal *et al*., 2009). But, there was no significant difference for correlation analysis showed with time. This is a significant finding for matured compost material over pond treatments.

Correlation analysis (Table 4) for the effects of time and depth on the C/N ratio of treated

POME sludge shows insignificant difference with time (month) and depth. According to Baharuddin *et al*. (2010), the composting material was at the accepted level when the POME sludge has reduced its C/N ratio. In addition, the C/N ratio of this composting material decreased in the latter stage of treatment.

Moisture Content

Table 3 shows the relationship between time (month), and depth characteristic for moisture content of treated POME sludge. The ANOVA results indicated that the effects of moisture content was insignificantly correlated with the depth except for time (month) (4.30*). However, time (month) showed a negative correlation with moisture (r = -0.379*) in Table 4.

According to Cai *et al*. (2013), the time domain reflects the measured moisture content of compost sludge. However, it was significant depending on the temperature but in this study was not observed temperature as a factor.

pH Value

The analysis of variance (ANOVA) for the effects of time and depth, their interaction with the pH value from treated POME sludge is shown in Table 3. Time factor had affected the pH value significantly except for depth. The correlation analysis (Table 4) further revealed that the pH value showed positive correlation with time (r = 0.44*). According to Texier (2008), the charge on sludge's particles strongly depended on the pH. According to Gillberg *et al*. (2003), almost all solid particles have a negative charge. With decreasing of pH, the number of positive charges increased and caused the surface charge of sludge particles nearly neutral. Interaction effects between time and depth showed no significant difference in the pH value. A decreased pH, has caused a reduction in the methanogenic activity and biomass. (Kobya *et al*., 2006; Sunada *et al*., 2012)

Solid Analysis

The reduction of sludge as measured by the volatile solids indicated the completeness of the digestion process (Bhattacharya *et al*., 1996). The characteristics of solid analysis from treated POME sludge content is presented in Table 3. Factor of depth had shown no significant difference in the solid analysis (total solid and volatile solid). However, there was a significant effect with the time (total solid) (4.30*).

The correlation analysis (Table 4) revealed insignificant correlation between solid analysis (total solid and volatile solid) and depth (r = 0.03ns and -0.03ns). This might be caused by the consistency of decomposition process contributed significantly towards microbial activities. Volatile solid content was used to determine the methane yield (Bhattacharya *et al*., 1996). This was due to the fact that volatile reduction showed gasses released into the atmosphere by the digestion which involved the methogenesis process. Then, the total solid represented the weight of actual dissolved and suspended solid in POME sludge. Total solid (TS) will not be obtained if the micro-organism presents in the digestion process. It will avoid the decomposition process effectively (Baharuddin *et al*., 2010).

Heavy Metal

The analysis of variance (ANOVA) on the effects of time (month) and depth (dumping pond) and their interaction with the treated POME sludge is shown in Table 3. All the main factors of time and depth content were found no significant difference in all element of heavy metals except for the depth factor of Zn (3.59*). The interaction effects of time showed a significant interaction in Cd (4.84*).

The correlation analysis (Table 4) indicated that the time (month) and depth (dumping pond) showed no significant correlation between heavy metal elements (Cr, Cd, Zn and Pb). According to Bigdeli and Seilsepour (2008), Cadmium is a highly mobile metal, easily absorbed by the plants through root surface and moves to wood tissue and transfers to the upper parts of the plants. The main source of cadmium in the air is from the burning fossil fuels such as coal or oil which is similar with the incineration process from municipal waste (EPA, 2000).

Nutrient Element

Summary of the ANOVA from treated POME sludge based from the interaction of time and depth is shown in Table 3. There was a significant effect on the element of Ferum (Fe) and Potassium (K). This was further revealed by the correlation analysis (Table 4) which indicated a highly positive correlation of Fe (r = 0.48*). However, K and Mg was observed as negative correlation between r = -0.48* and r = -0.41*. According to Sharma and Singh (2001), micro-nutrients such as Fe under mesophilic conditions, Potassium and Phosphate are detrimental and affect the efficiency of treatment and sludge granulation.

Effects of Time

CHNS-O Elements

Table 3 shows the effects of time on CN elements in treating POME sludge sample. Carbon (C), Nitrogen (N) and Oxygen (O) showed a significant difference. The correlation analysis (Table 4) further revealed that a positive correlation for oxygen element (r = 0.478**), but a negative correlation was observed for Carbon (C), Nitrogen (N) (r = -0.509** and r = -0.539**). According to Bolzonella *et al*. (2005), a longer retention time is needed for digestion process of sludge in wastewater treatment and may lower the gas production. Zitomer and Shrout (1998) indicated that oxygen can promote different degradation reactions from various compounds and with different mechanisms.

C/N Ratio

Table 3 shows the effects of time for C/N ratio from the treated POME sludge. Statistical analysis indicated that there was a significant interaction between the month of June and July (7.13a and 7.23b). C/N ratio was observed significantly from the moisture content and temperature effects. According to Wan Razali *et al*. (2012) it happens because of the process during the thermophilic phase.

The thermophilic phase is the process of bacterial action to degrade the organic matter. The decomposition process would involved the cellulose, hemicellulose and lignin. Moreover, cellulose and hemicellulose, which have high C content, was commonly degraded earlier while lignin would be degraded at the later stage (Wan Razali *et al*., 2012). In addition, lignin provided a strength to the plant against the microbial degradation process (Jouraiphy *et al*., 2005). Wong *et al*., (2008) reported that lignin was not deteriorated by enzymes and it shields the cellulose during the hydrolysis process. The final C/N ratio was calculated at 7.41. The data showed that the POME sludge sample was statutory as matured compost material based on a C/N ratio of 15 or less.

Moisture Content

The significant difference was observed on the time when moisture content decreased from 76.32a to 74.33b (Table 3). The correlation analysis (Table 3) further revealed that the moisture content values showed a negative correlation of -0.379*. This may indicate that the presence of water area in the dumping pond in January contributed to a higher moisture content compared to the month of June. Moisture of the dumping pond would increase due to the rainfall events.

pH Value

Table 5 shows the summary of t-test on the effects of time and pH. The time retention of the treated POME sludge significantly affected the pH value. The correlation analysis (Table 4) further revealed that the pH value showed a positive correlation with time (r = 0.440*). According to ASCE (2009), the variation of pH value was found after the sample was taken every month from each treated sludge.

Solid Analysis

Time affected the total solid and volatile solid significantly. This was further revealed by correlation analysis (Table 4) which indicated that the characteristic of total solid with time increased (r = 0.38*). The higher volatile solid (VS) value in the POME sludge (dumping pond) might be due to the presence of beneficial predominant microbial for composting treatment such as bacteriodetes. It was previously detected in partially treated POME through the denaturing gradient gel electrophoresis (Baharudin *et al*., 2010). Indeed, the volatile solid (VS) amount gives an idea of the organic substance content which was available in the digestion treatment process. Due to the intensive duration process of the decomposition treated POME sludge, very low content of volatile solid (VS) is considered common. It contained a relatively high level of ash.

Furthermore, total solid represented the substrate that tough and harder to be digested by the microbes. Moreover, total solid value was a proportion of carbohydrate constituents, both soluble and insoluble. This level of oil could clarify the sludge in terms of oil percentage per solids and in comparison with the POME provided further evidence of the substantial oil loss associated with the particulate fraction.

Heavy Metal and Nutrient Elements

The t-test for the effects of time (month) on heavy metal and nutrient is shown in Table 5. There was no significant different between heavy metal and nutrient on the effects of time (Jan and June). The correlation analysis (Table 4) further revealed that the time of heavy metal and nutrient showed insignificant correlation with all the elements. However, Li and Wu (2014) report that sludge time is an important factor which affects not only the performance of nutrient removal but also the sludge characteristics and the production of secondary pollutants such as carbon dioxide, nitrous oxide and methane. Indeed, this would also enhance the nitrification and reduced excess sludge production (Li and Wu, 2014). This indicates that treated POME sludge had become a stable sludge in term of its characteristic. These were also proven by the correlation analysis which is similar to the depth.

Effects of Depth

CHNS-O Elements

The effects of depth of CNO elements is shown in Table 6. There was no significant difference between the depth (one, two and three meters) on CNO elements. According to EPA (2000) the minimum depths would give an effect of oxygen diffusion from the surface, allowing anaerobic conditions to happen successfully.

C/N Ratio

The effect of depth as shown in Table 6 indicated that there was no significant difference. Correlation analysis (Table 4) for C/N ratio shows insignificant increment with depth (0.26ns).

Moisture Content

The analysis of t-test on the effects of depth and moisture content was observed in the treating POME sludge in Table 4. All the depths in dumping pond were found no significant difference. In this study, treated POME sludge was observed to have an optimum moisture content (75%).

The moisture content on the final stage of matured compost was identified at 50-70%. Within the thermophilic process the temperature contributed to water loss and increased evaporation during the decomposition process. According to Wan Razali *et al*. (2012) the optimum moisture content of 55% was required for composting process. In addition, the treated POME sludge was essential to sustain the microorganism activity and also as a nitrogen sources.

pH Value

Table 6 shows the characteristic on the effect of depth on pH test. All the depths range were found no significant difference with pH. According to Yan *et al.* (2008) pH value associates with the sludge surface range. However, this is probably due to the less watering of dumping pond within the the range of 50-70%.

Table 5. The summary of T-test on the effects of time on treated POME sludge

Time (month)	C (%)	N (%)	O (%)	C/N ratio	MC (%)	pH	TS (%)	VS (%)	Cr (mg kg^{-1})
Jan	25.52 a	3.58 a	0.47 a	7.13 a	76.32 a	7.41 a	23.68 a	85.26 a	3.08 a
June	24.51 b	3.39 b	0.40 a	7.23 b	74.33 b	7.82b	25.67 b	85.17 b	2.95 a

Table 5. *(Continued)*

Time (month)	Cd (mg kg^{-1})	Zn (mg kg^{-1})	Pb (mg kg^{-1})	Fe (%)	K (%)	Ca (%)	Mg (%)	P (%)
Jan	0.04 a	21.7 a	0.43 a	0.11 a	0.01 a	0.15 a	0.08 a	0.01 a
June	0.06 a	15.7 a	0.62 a	0.13 a	0.01 a	0.29 a	0.12 a	0.01 a

Remarks: Means with the same letter down the column are not significantly different at $p<0.05$

Table 6. The physicochemical composition of the treated POME sludge with correlated depth

Depth (meters)	C (%)	N (%)	O (%)	C/N ratio	MC (%)	pH	TS (%)	VS (%)	Cr (mg kg^{-1})
1	25.01 a	3.52 a	65.86 a	7.12 a	75.10 a	7.40 a	24.90 a	85.51 a	27.69 a
2	25.09 a	3.51 a	65.74 a	7.16 a	76.00 a	7.69a	24.00 a	84.79 a	27.78 a
3	25.96 a	3.44 a	65.76 a	7.27 a	74.88 a	7.75 a	25.12 a	85.35 a	28.09 a

Table 6. *(Continued)*

Depth (meters)	Cd (mg kg^{-1})	Zn (mg kg^{-1})	Pb (mg kg^{-1})	Fe (%)	K (%)	Ca (%)	Mg (%)	P (%)
1	0.40 a	159.78 a	5.65 a	2.24 a	0.03 a	1.67 a	0.53 a	0.08 a
2	0.43 a	181.23 b	5.70 a	2.24 a	0.03 a	1.76 a	0.61 a	0.09 a
3	0.39 a	169.32 ab	5.71 a	2.24 a	0.03 a	1.57 a	0.51 a	0.08 a

Remarks: Means with the same letter down the column are not significantly different at $p<0.05$

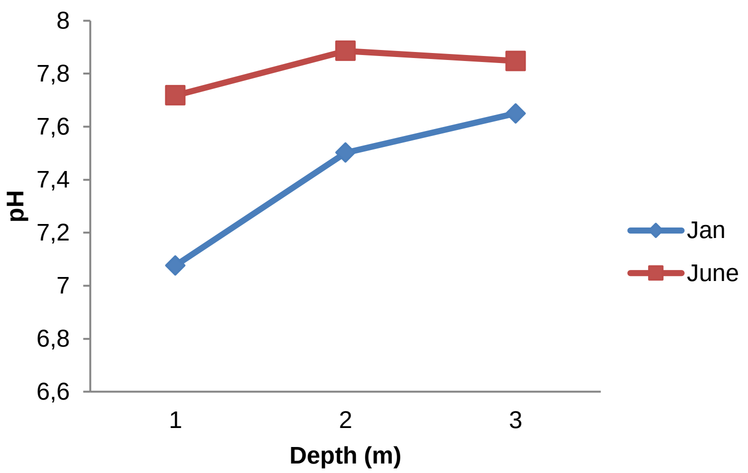

Figure 2. pH measurement on treated POME sludge in the dumping pond.

The initial pH of treated POME sludge increased from 7.07 to 7.56 within the first depth until the third depth. Figure 2 showed the trend of change in pH measurement starting from June and July 2014. The pH value was increased with the depth. The average range of pH was 7.50 and suitable for microorganisms to grow and develop. pH of treated POME sludge was observed in the range of 6.0 to 8.5 and suitable for most types of plants (Wan Razali *et al*., 2012; Hachicha *et al*., 2009). There was no significant difference found betwen the depth of the dumping pond and pH parameter.

Solid Analysis

The summary of ANOVA on the effects of depth and treating POME sludge is given on Table 4. The treated POME sludge showed that the all depth were not significantly different at $p<0.05$. The value of total solid and volatile solid in depth increased with a consistent trend. Negative effect occurs with differrent depth and could enhance the methane production (Zhang *et al*., 2010).

Heavy Metal and Nutrient Elements

Table 6 shows the summary of t-test on the effects of depth on heavy metal and nutrient. The statistical analysis shows no significant difference in heavy metal (Chromium, Cadmium, Zinc and Plumbum) and nutrient (Ferum, Potassium, Calcium, Magnesium and Phosphorus). According to Richards *et al*. (2000) the composted sludge has the lowest heavy metal mobilities.

Treated POME sludge can be classified as a composted sludge with the present of certain characteristics.

There were 4 elements of heavy metal traced in the sludge samples. In each sample was detected with different components, including Zinc (Zn), Chromium (Cr), Plumbum (Pb) and Cadmium (Cd). In the results, Boron (B) was not detected. According to Sharma *et al.* (2007) only certain heavy metal is significantly effect human health such as Plumbum (Pb) and Cadmium (Cd). In addition, the bacteria in the anaerobic digestion process required micro-nutrient and trace elements such as nitrogen, phosphorus, sulfur, potassium, calcium, mag-nesium, iron, nickel, cobalt, zinc, manganese and copper for optimum growth performance (Rajeshwari *et al*., 2000). Although these elements are needed in extremely low concentrations, the lack of these nutrients will give an adverse effect on the microbial growth and performance.

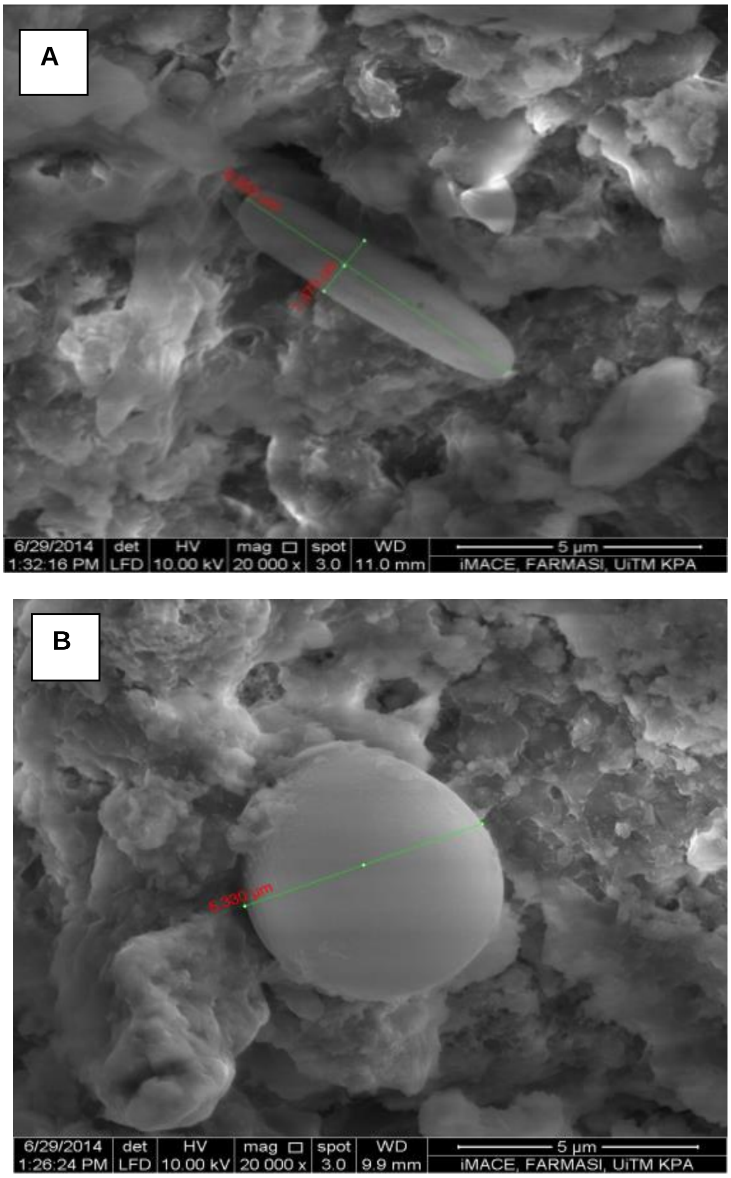

Figure 3. FESEM micrograph (Magnification 20000x) treated POME sludge structure with acetogenic and methanegenic bacteria in dumping pond

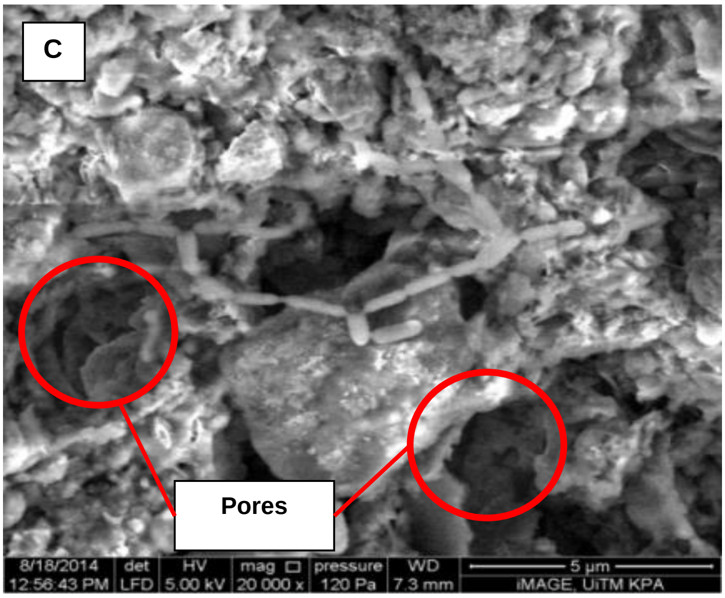

Figure 4. FESEM micrograph (Magnification 20000x) detected colonization of acidogenic bacteria and pores structure in treated POME sludge

According to Baharuddin *et al*. (2010), methane forming bacteria has a relatively high internal concentration of iron, nickel and cobalt. However, these elements may not present in sufficient concentration in the wastewater stream. Indeed, the nutrient concentration in the effluent should be adjusted based on the minimum nutrient concentration. In such cases, the waste-waste has to be supplemented with the trace elements in the optimum requirement of C:N:P ratio (Hulshoff, 1995) in enhancing yield of methane as 100:2.5:0.5 The minimum concen-tration of macro and micro-nutrient can be calcu-lated based on the bio-degradable COD concen-tration of the wastewater.

The low level of heavy metal elements in treating POME sludge might be caused by the direct treatment of fresh raw POME for methane production in the digestive process (Baharuddin *et al*., 2010). The result obtained in the experiment proved that the sludge was safe and suitable to be used as an organic fertilizer.

Morphology of Treated POME Sludge

Field emission scanning electron micro-scope (FESEM) was conducted to understand the degradation of POME sludge morphology throughout the palm oil effluent treatment process. FESEM is a tool to assist description of sample through observation. Micrographs for POME sludge in different depth and month was shown in Figure 1. The sample was taken randomly consisting of point A, B, C, D and E. Each sample was analyzed in the scanning electron micro-scope for physical characteristic, appearance of any microbial and structure contributing to methane and biogas yield. Formation of pores were represented in a structure of remaining solid particle and fiber that still remain in the POME sludge. Pores were the activated sludge for methanogens (Figure 4). It also plays a significant role in the physical membrane of POME sludge (Clark *et al*., 1991).

Microorganisme of Treated POME Sludge

Micro-organism in treating POME sludge could help the digestion process. This study identified the microorganisms of anaerobic bacteria such as methanegenic bacteria (1), acetogenic bacteria (2) and acidogenic bacteria (3) (Figure 3 and Figure 4). According to Mata-Alvarez (2003) these bacteria activites are important in the process of decomposition and also assisting the production of methane in the process.

CONCLUSION AND SUGGESTION

The physicochemical characteristics had been analyzed on the effect of time (month) and depth (dumping pond). The results showed that C and N were insignificantly correlated with time but positively correlated with O content. Time and depth were not affecting the C/N ratio and heavy metal element (Cr, Cd, Zn and Pb). Fe showed a significant correlation with time increased and correlated negatively with K and Mg. The moisture content showed a negative correlation with the increased of time but correlated significantly with pH. However, the effect of depth showed no significant difference with the physico chemical characteristics. This study identified the present of anaerobic microorganisms such as methanegenic bacteria, acetogenic bacteria and acidogenic bacteria. These bacterias were important to help decomposition process of the treated POME sludge to become an organic fertilizer. Generally, time (one and six months) was found significantly affect certain physicochemical characteristics such as O, Fe and pH. In conclusion, treated POME sludge from the dumping pond is safe and recommended to be used as an organic fertilizer. In the future experiment, the treated POME sludge can be tested with soils and crops to observe its potential as an organic fertilizer.

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