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ENGINEERING

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ENGINEERING

A Study on the Effectiveness of Palm Oil Mill Effluent (POME) Treatment Systems

Caroline Marajan
Rosliana Rozali

ABSTRACT

Malaysia is one of the leading countries in producing and exporting palm oil. The production process bulk quantities of high strength palm mill effluent. The palm oil industry contributes to the environmental problem due to the effluent. The palm oil effluent must be treated using appropriate systems to reduce the hazardous substances and volume of the effluent. Hence, the study on the effectiveness of these treatment systems are investigated to compare certain parameters such as pH, suspended solids, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) with the guidelines established by the Environmental Quality Act 1974 (EQA). The study consists of two palm oil mill effluent treatment systems which are the ponding system (Kalumpong Oil Mill) and open tank digester system (Chersonese Oil Mill). Samples were taken from both palm oil mills for laboratory testing and on-site testing for the identified parameters for the treatment systems. The effectiveness for both palm oil mill effluent treatment systems depends on the treatment stages that provide different effect according to the treatment processes that have been done and the removal efficiency of BOD, COD and suspended solids for both treatment systems from the lab and on-site results.

Keywords: *Palm oil mill effluent, ponding system, open tank digester system, wastewater treatment system*

Introduction

Palm oil mills generate large quantities of liquid waste which is commonly referred to as palm oil mill effluent (POME). In earlier days, the palm oil mill effluent was conveniently discharged into nearby water courses to be diluted by the rivers and streams. However, due to rapid expansion of the palm oil industry and with the increase of environmental awareness, the industry has to treat its effluents to an acceptable level before it is discharged to the environment. Due to this the subject of palm oil mill effluent and its impact on the environment becomes a critical issue which concerns the government and the public. Hence, the government acted responsibly by enacting the Environmental Quality Act 1974 and specific regulations governing the discharge in watercourse and land came into force on July 1978. Since then it became mandatory for all palm oil mills to treat their effluents on site according to the guidelines before it is allowed to be discharge to watercourses.

In 1997, Malaysia produced about 32 million tonnes of POME from 290 palm oil mills and generated about 0.8 million tones of BOD. In terms of biochemical oxygen demand (BOD) which amounts to 25,000 mg/l, it is highly polluting. It is 100 times more polluting that domestic sewage. As well as high biochemical oxygen demand (BOD) and chemical oxygen demand (COD), its high solid content causes treatment method to be costly and complex. More than 85% of the palm oil mills in Malaysia are practicing ponding system as treatment method for POME. The country's Environment Quality Act 1974 presented in Table 1 clearly states that all palm oil mills must treat POME to reduce the BOD to a level of less than 100mg/l for watercourse discharge and 5000 mg/l for land application. However, most mills have the difficulty to treat the effluent to below 100 mg/l consistently. (Gurmit et al., 1994)

Table 1: POME Parameter Limit for Watercourse Discharge
(Environmental Quality Act, 1974)

Parameters	Limits
Biochemical Oxygen Demand, BOD (mg/l)	100
Chemical Oxygen Demand, COD (mg/l)	1000
Suspended Solids (mg/l)	400
Oil and Grease (mg/l)	50
Ammonia Nitrogen (mg/l)	150
Total Nitrogen (mg/l)	200
pH	5 - 9

In palm oil milling, large amount of water is required about five to seven tonnes of water. Two to three tonnes are used as boiler feed water and the remainder as process water such as for dilution and washing. About half of the water used end up as palm oil mill effluent and the rest as steam through sterilizer exhaust and leakages. Palm oil mill effluent is mainly generated from oil extraction process and has great impact on the environment. Owing to its chemical properties and volume of discharge, a large waste water treatment system is required to reduce the pollution strength of POME before being discharged to streams. The selection and performance of the treatment system determines the quality of the palm oil mill effluent. There is very little information available on the treatment of palm oil refinery effluent in Malaysia. Osenga introduce a treatment process consisting a Cross Flow Interceptor (CFI) for oil separation, physical and chemical treatment and air flotation units to remove the flocks followed by a batch-wise activated sludge process for the liquid effluent treatment. This process also required close supervision in order to achieve the desired treatment efficiency (Osenga, 1980). Therefore, the main focus of this study is to identify the effectiveness of POME treatment system according to the parameter limits set by the Environmental Quality Act 1974.

Characteristics of Palm Oil Mill Effluent

Fresh palm oil mill effluent appears as thick brownish colloidal slurry of water, oil and fine cellulose fruit residuals. It is hot around 80°C to 90°C and quite acidic. Table 2 provides range of values for a common palm oil mill effluent. Suspended solids that are present in POME are principally cellulosic substances from fruit. This is because about one tonne of water including boiler feed water is required to process one tonne of fresh fruit bunches (FFB). POME is non-hazardous as no chemical is added during the milling process. Nevertheless, POME still contains substantial amount of nitrogen, phosphorus, magnesium and calcium which are important nutrient elements for plant growth.

Treatment Processes for Palm Oil Mill Effluent

POME contains very high organic matter as is reflected by its BOD. Biological treatment of wastewater depends on active microorganisms which consume the organic substances produced by the wastewater as nutrients for a period of time where it is sufficient for the microbes to

Table 2: Characteristics of Palm Oil Mill Effluent (Ma et al., 1985)

Parameter	All parameters unit in mg/l except pH	Parameter	All parameters unit in mg/l except pH
pH	4.7	Phophorous	18
Oil & Grease	4000	Potassium	270
BOD	25000	Magnesium	615
COD	50000	Calcium	439
Total Solid	40000	Boron	7.6
Suspended Solid	18000	Iron	46.5
Total Volatile Solid	34000	Manganese	2.0
Ammoniacal Nitrogen	35	Copper	0.89
Total Nitrogen	750	Zinc	2.3

digest or remove the organic pollutant from the polluted water. The treatment process for palm oil mill effluent can be anaerobic, aerobic or facultative. (Cheah & Ma, 1985)

Anaerobic process is where microbes are utilized to break down organic matter without the presence of oxygen. The result is the conversion of organic compounds into several end products such as water, methane, carbon dioxide and stabilized solids. Aerobic treatment process has been agreeable for palm oil mill effluent from edible oil refineries. The application of activated sludge process or aerated lagoon is in this perspective is well established in the edible oil industry. The basic principle of the process is that the effluent is brought into contact with a mixed population of microorganisms in an aerated basin. (Chin & Wong, 1981)

The effluent from the edible oil refinery tends to be scarce in nitrogen for aerobic biological treatment. Nitrogen has to be added to meet the nutrient requirement. As for facultative ponds, the design is based upon biochemical oxygen demand removal. However, the majority of the suspended solids will be removed in the primary cell of a pond system. The solids which settle out in a pond undergo digestion and provide a source of organic compounds to the water, which is significant and has an effect on the performance.

Palm Oil Mill Effluent Treatment Systems

Ponding System

There are various designs and configurations of ponding systems that are being used for POME. The ponds are mostly earthen structures with no lining. The primary treatment takes place in the anaerobic pond, which is mainly designed to remove suspended solids and some of the soluble element of organic matter (BOD_5). During the secondary stage, the facultative pond, most of the remaining BOD_5 is removed through the coordinated activity of algae and heterotrophic bacteria. The main function of the tertiary treatment, the maturation pond is the removal of pathogens and nutrients (especially nitrogen).

Ponding systems were reported to be reliable, stable and capable of producing good quality of final discharge with BOD less than 100 mg/l, which meets the regulatory watercourse discharge. Furthermore, ponding system is cheap to construct but requires a large land area. The anaerobic ponds are usually 5 to 7 meter deep while the facultative ponds are 1 to 1.5 meters in depth. The hydraulic retention times for these systems are 1, 4, 45 and 16 days for de-oiling tank, acidification, anaerobic and facultative ponds respectively. Ponding systems are normally operated at very low rate. Another feature of the ponding system is the build up of solids at the bottom of the pond. If the solids are allowed to accumulate to excessive levels, they together with the scum at the top will effectively reduce digester capacity and shorten the retention time. This will adversely affect the treatment efficiency of the process. Figure 1 shows the schematic diagram for ponding system at Kalumpong Oil Mill, Kerian, Perak Darul Ridzuan.

Open Tank Digester System

Palm oil mill effluent in the open tank digester system is treated after the oil recovery pit, in tanks in a two phase anaerobic digestion process followed by extended aeration. The digester is made of mild steel. The treatment system is open at the top and the effluent is left unstirred. The digesters usually are constructed with individual capacity of 600 to 1,800m^3 and with a height of 10 meter. The retention time for the acidification, anaerobic and aerobic process is normally 1, 25 and 25 days respectively. The organic loading of the digester is in the range of 0.8 to 1.0 $kg/m^3/day$.

Similar to the ponding system, mixing in the anaerobic digester is provided by the increasing biogas generated by the process. Being inadequate, this system faces the same problem of scum formation at the top and solids build up at the bottom of the digester. However, these problems are much simpler to control and manage in the tank digesters. The rate of solid build-up can be easily monitored. Excess solids have to

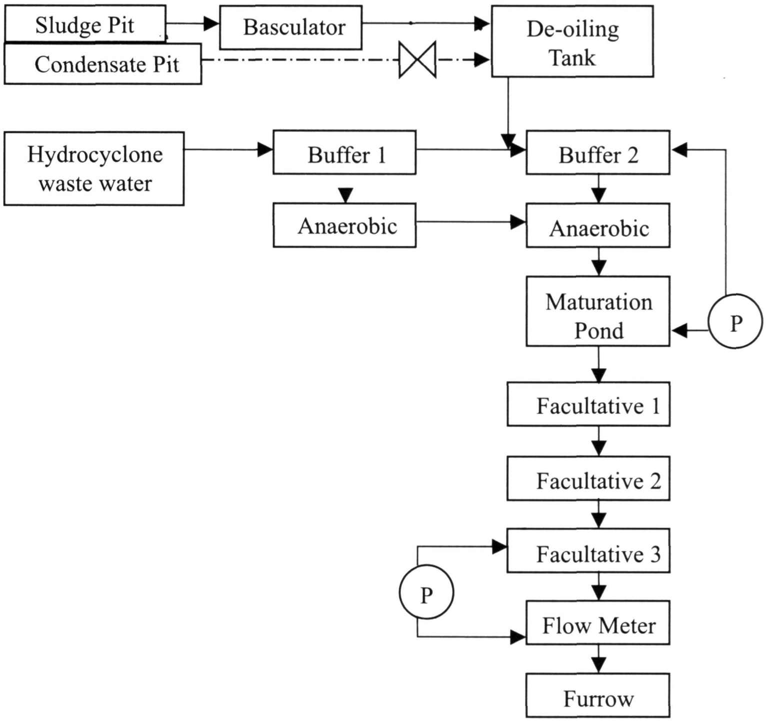

Figure 1: Schematic diagram of ponding system for Kalumpong Oil Mill (Guthrie Group, 2005)

be removed regularly and disposed off as in the ponding system or taken away for land application. For that reason, the efficiency of the anaerobic process can be maintained at fairly consistent level, with BOD removal efficiency of more than 95%. For further reduction, the anaerobic liquor is treated in extended aeration ponds. Mechanical surface aerators are used to supply air to the aerobic process. Figure 2 shows the schematic diagram for open tank digester system and Table 3 shows the pond retention time for Chersonese Oil Mill, Kerian, Perak Darul Ridzuan.

Materials and Method

Data Collection

The palm oil mill effluent samples were collected from two palm oil mills, which are Chersonese Oil Mill with open tank digester system and the Kalumpong Oil Mill with ponding system located in Kerian, Perak.

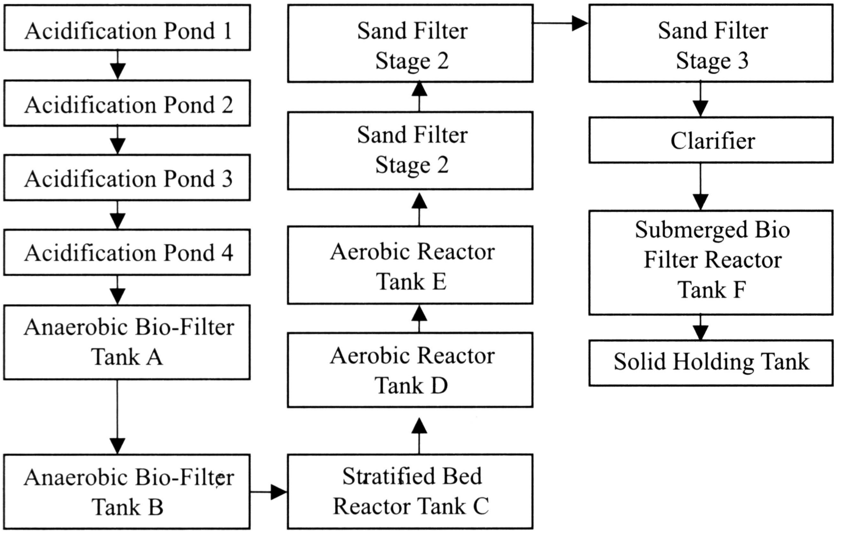

Figure 2: Schematic Diagram of Open Tank Digester System for Chersonese Oil Mill (Golden Hope Plantation Bhd., 2005)

Table 3: Pond Retention Time (Golden Hope Plantation Bhd., 2005)

Pond	Volume (m^3)	HRT (hr)
Pond 1	1589	53
Pond 2	2805	94
Pond 3	2805	94
Pond 4	5865	196
Anaerobic Bio-Filter (Tank A & B)	1273	42
Stratified Bed Reactor (Tank C)	551	18
Aerobic Reactor (Tank D & Tank E)	180	27
3 Stages of Sand Filter	60	2
Clarifier		
Submerged Biofilter Reactor (Tank F)	470	16
Solid Holding Tank	36	1
Total Volume & Retention Time	16264	543
Pond 5	5865	196
Pond 6	5865	196

Samples were taken from the inlet (before treatment) and outlet (after treatment) of the treatment system and brought to the laboratory for analysis. pH was measured on site. Palm oil mill effluent samples were taken regularly for three days in a week for both mills. All samples were preserved and tested on the same day. Samples were tested for suspended solids, BOD_5 and COD.

Laboratory Testing

For more accurate result samples must be test on the same day and done on-site. Some test like an example temperature test or pH is more accurate done on-site test using pH and temperature probe. However, samples can be brought back to the lab following the right procedures to preserved samples.

BOD_5 tested by using a dissolved oxygen meter. Initial readings for dissolved oxygen were taken; meanwhile, final readings were taken after 5 days. For COD lab testing, Merck Photometric Cell Test 14540, measuring range 10-150mg/l COD method were used. The thermo-reactor TR 205 used to digest effluent before testing for COD using a spectrometer apparatus.

Suspended solids of the effluent can be examined by using filtration apparatus whereby the effluent will be filtered using filter paper. Filter paper must be dried in the oven before it is used for filtration. Effluent filtered in the filtration apparatus and dried in oven. The final weight is the amount of suspended solids in the sample.

Result and Discussion

The results for the tested parameters from the inlet and outlet of the treatment system are presented in Tables 4, 5, 6 and 7. Figures 3, 4, 5 and 6 show the comparison of results for pH, BOD, COD and suspended solid for both systems. Figures 7, 8 and 9 show the removal percentage for BOD, COD and suspended solids. The mean treated effluent characteristics are shown in Table 8 and Table 9.

Overall, the results showed that open tank digester system provided higher removal of BOD, COD and suspended solids. However, both treatment systems for POME showed compliance with the allowable limits stipulated in EQA. Fresh palm oil mill effluent is quite acidic with pH of 4.7 (Table 2). For that reason acidification ponds are used for pH

Table 4: Results for pH and Suspended Solids in Ponding System (Kalumpong Oil Mill)

Sample	pH		Suspended Solids mg/l	
	Inlet	Outlet	Inlet	Outlet
1	5.07	7.22	103	23
2	4.86	8.41	108	27
3	5.28	7.79	98	26
4	5.53	6.88	98	25
5	5.77	7.21	107	31
6	4.89	8.76	97	27
7	5.14	7.79	95	29
8	6.16	7.64	101	24
9	5.39	7.21	106	28
10	5.44	6.71	96	20
11	5.43	7.05	90	32
12	5.23	6.54	103	36
13	5.89	6.32	100	34
14	4.99	6.74	93	29
15	6.07	6.75	97	37
16	5.51	7.03	96	38
17	5.28	5.66	110	40
18	5.81	5.83	83	22

Table 5: Results for pH and Suspended Solids in Open Tank Digester System (Chersonese Oil Mill)

Sample	pH		Suspended Solids mg/l	
	Inlet	Outlet	Inlet	Outlet
1	5.45	7.98	219	21
2	6.89	8.99	204	24
3	7.6	9.72	198	26
4	6.34	8.56	187	22
5	5.46	8.33	191	27
6	6.12	8.09	184	24
7	6.35	7.63	200	20
8	5.88	8.11	178	25
9	6.33	7.98	156	25
10	5.68	6.5	177	22
11	5.4	6.81	192	19
12	6.72	8.02	195	28
13	6.82	8.64	201	25
14	6.54	7.89	109	27
15	6.43	7.67	133	23
16	7.01	7.56	127	20
17	5.9	8.03	134	21
18	6.11	7.14	108	20

Table 6: Results for BOD and COD in Ponding System (Kalumpong Oil Mill)

Sample	Biochemical Oxygen Demand, BOD mg/l		Chemical Oxygen Demand, COD mg/l	
	Inlet	Outlet	Inlet	Outlet
1	87.3	71.4	1245	71
2	80.7	75.4	1472	56
3	70.5	84.1	1654	67
4	74.5	73.0	1356	59
5	81.0	65.7	1739	80
6	71.6	56.5	2076	76
7	95.4	87.5	987	57
8	70.6	56.2	1006	67
9	73.5	70.9	1157	62
10	90.3	86.6	1981	58
11	90.2	85.4	2315	93
12	90.6	87.0	928	71
13	107.8	88.3	1006	78
14	70.0	67.8	1211	73
15	72.3	69.3	765	59
16	102.3	96.1	883	65
17	61.2	45.9	1290	66
18	89.4	77.9	706	57

Table 7: Results for BOD and COD in Open Tank Digester System (Chersonese Oil Mill)

Sample	Biochemical Oxygen Demand, BOD mg/l		Chemical Oxygen Demand, COD mg/l	
	Inlet	Outlet	Inlet	Outlet
1	33.1	28.0	1530	44
2	34.4	21.3	1390	34
3	23.5	18.6	1465	46
4	56.5	34.0	1298	37
5	54.2	50.9	1783	42
6	34.1	32.2	1679	35
7	53.4	45.6	1281	37
8	24.8	21.1	1904	41
9	25.7	18.6	1160	41
10	19.9	12.4	1769	35
11	35.4	24.5	2145	51
12	31.1	29.0	1997	46
13	43.3	40.7	1875	43
14	36.7	32.0	1675	41
15	27.6	28.0	1576	45
16	43.1	28.0	1213	39
17	43.2	23.0	2144	48
18	26.8	19.3	1871	37

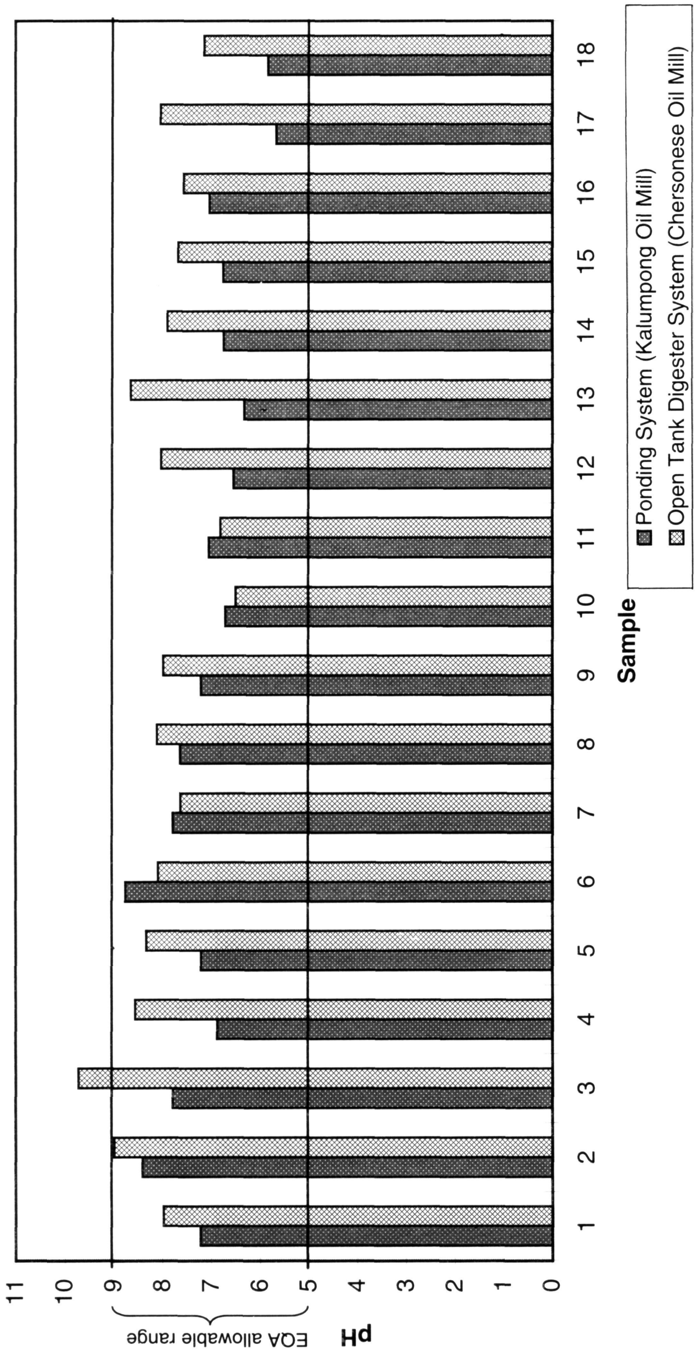

Figure 3: pH from the Outlet of POME Treatment Systems

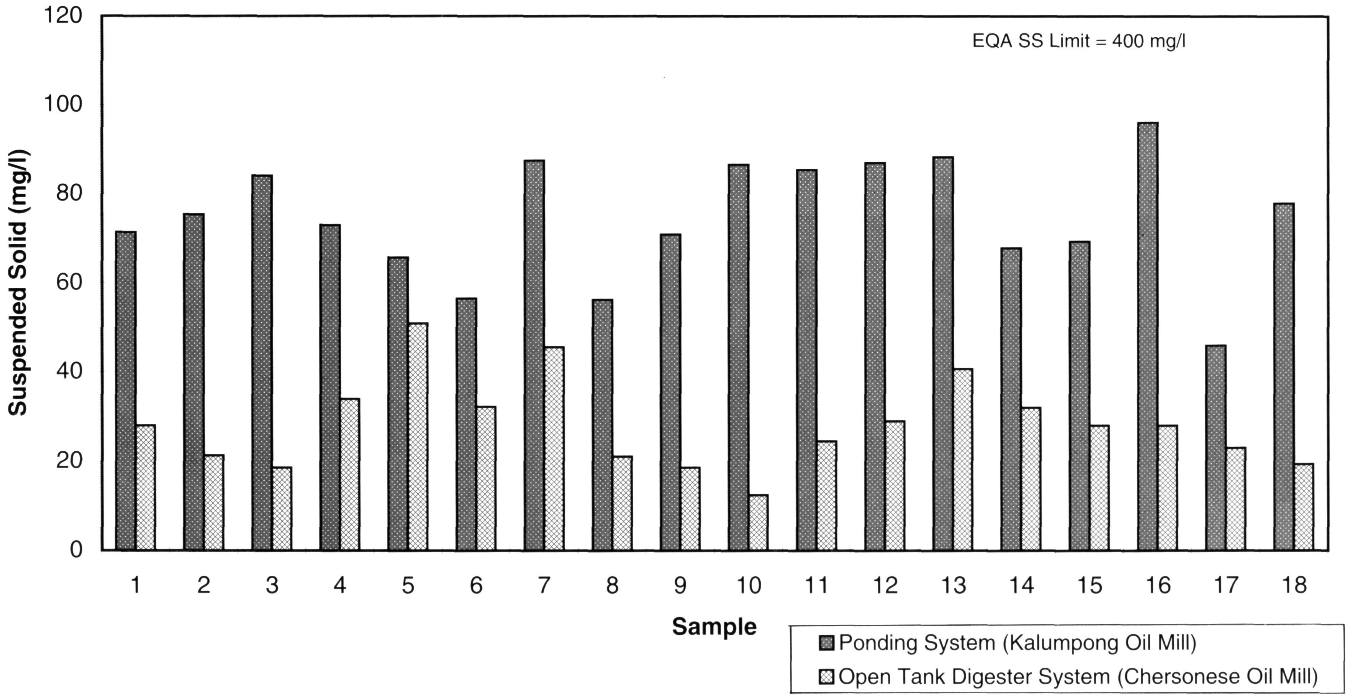

Figure 4: Suspended Solids from the Outlet of POME Treatment Systems

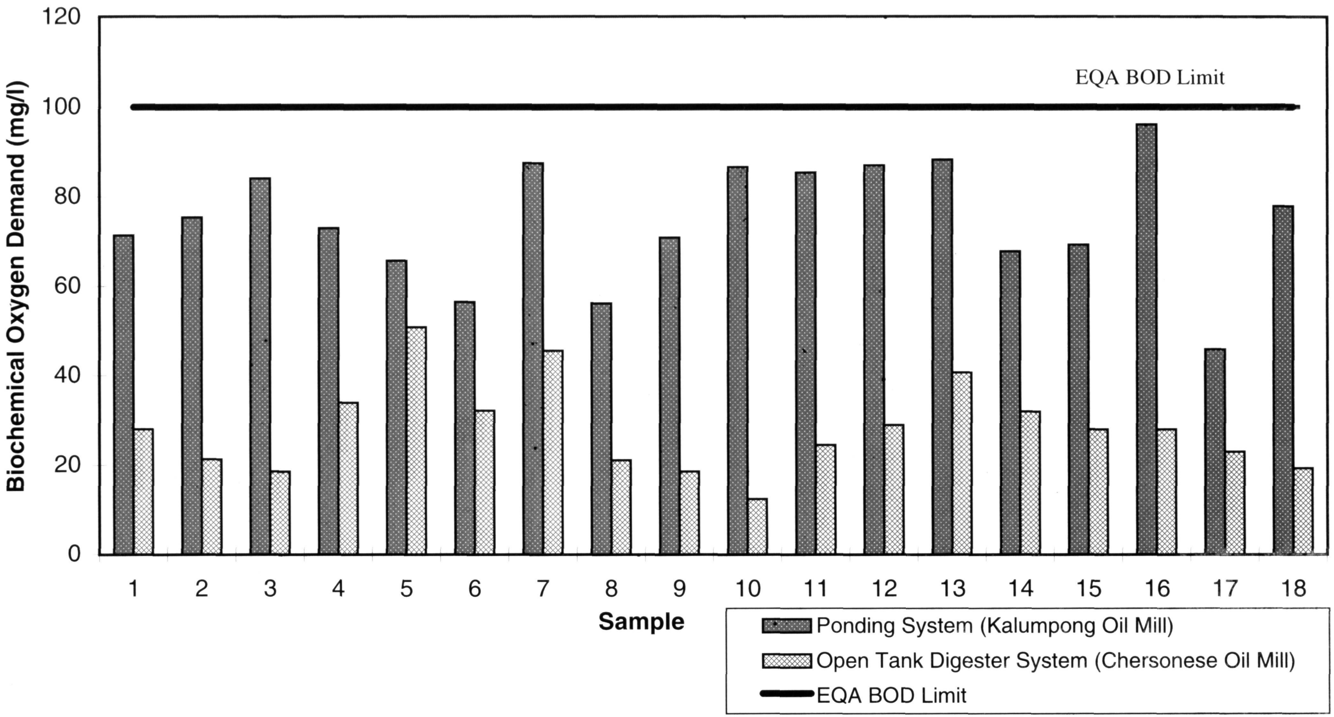

Figure 5: Biochemical Oxygen Demand from the Outlet of POME Treatment System

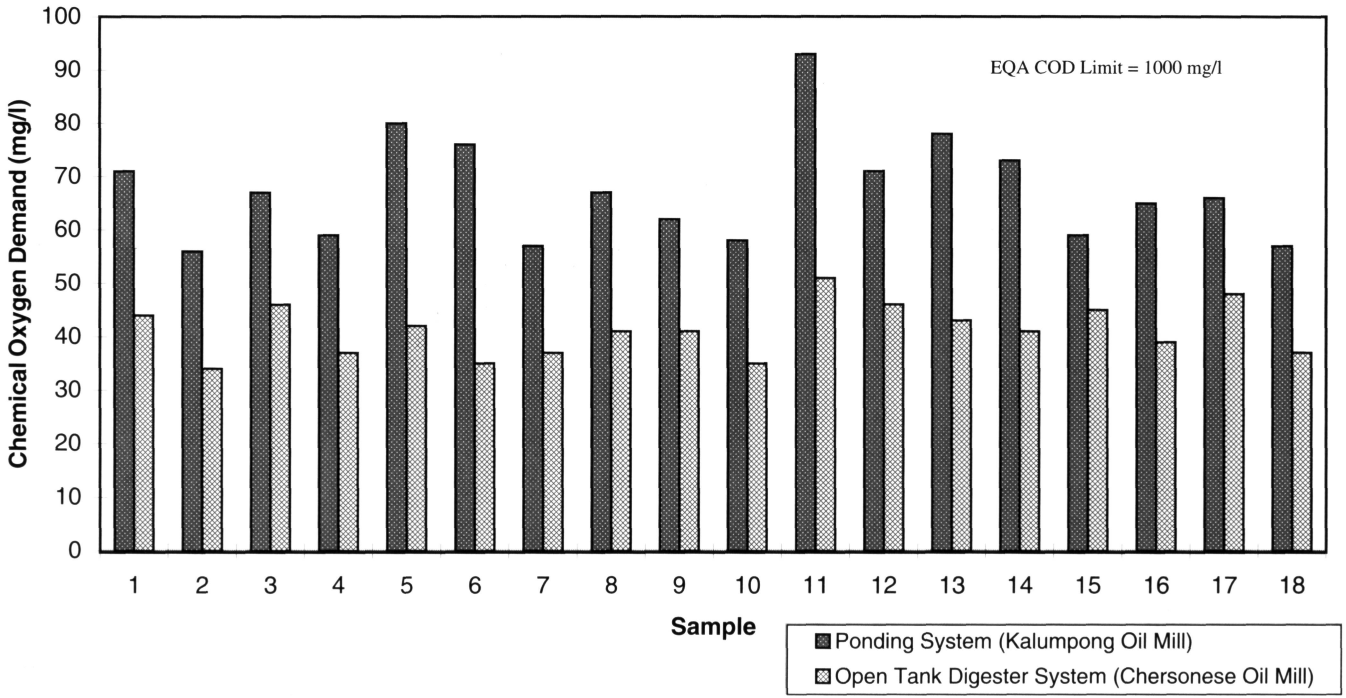

Figure 6: Chemical Oxygen Demand from the Outlet of POME Treatment System

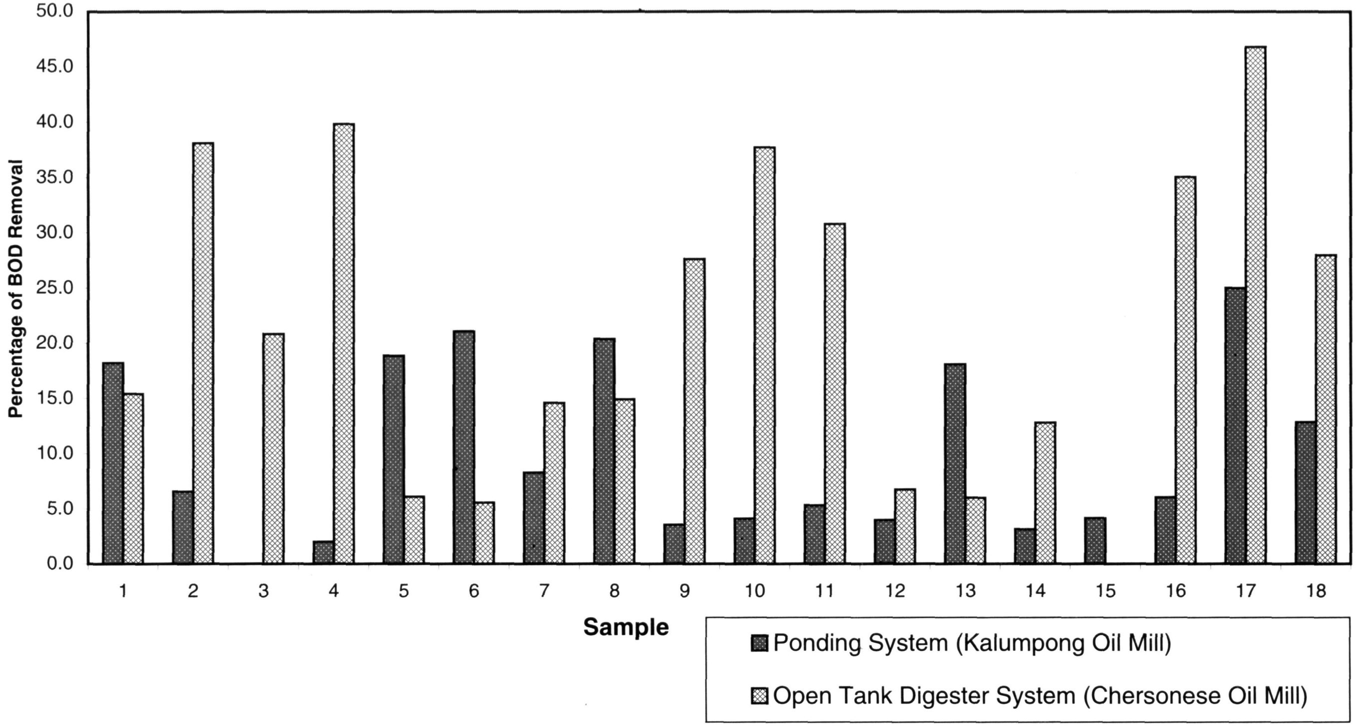

Figure 7: Percentages of Biochemical Oxygen Demand (BOD) Removal

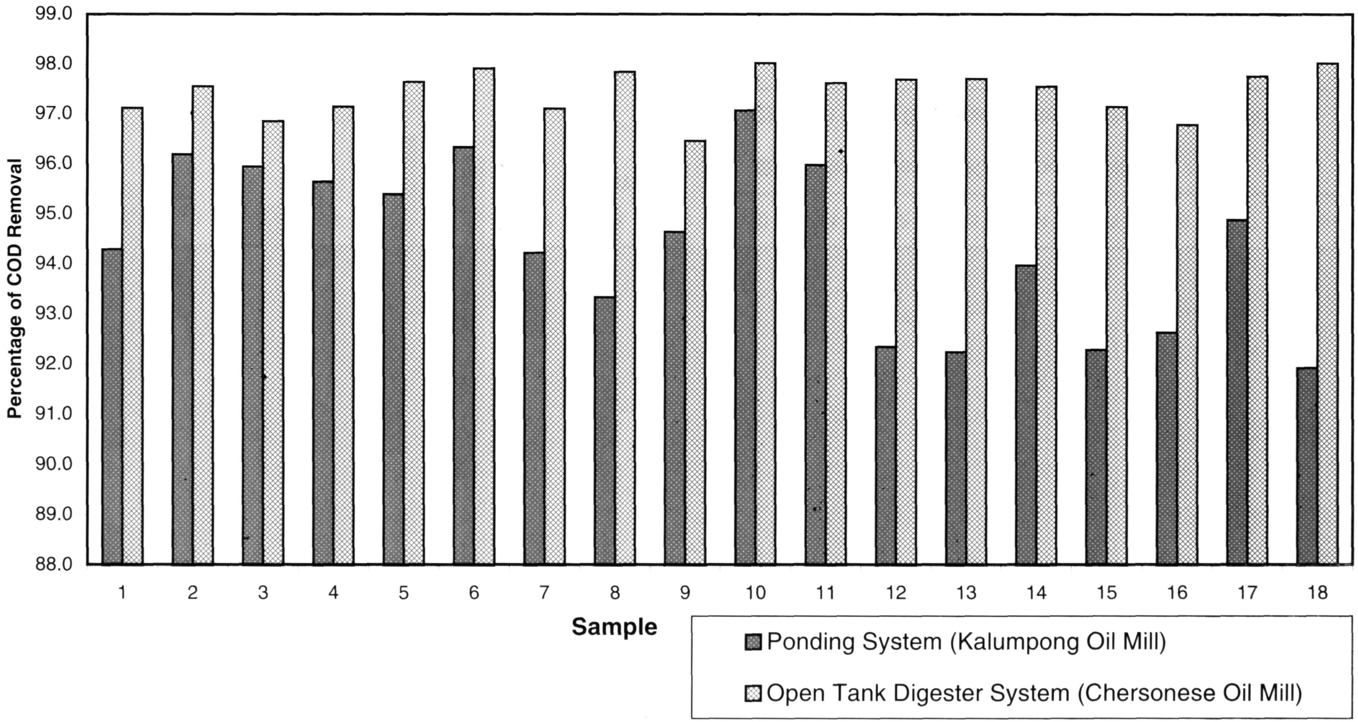

Figure 8: Percentages of Chemical Oxygen Demand (COD) Removal

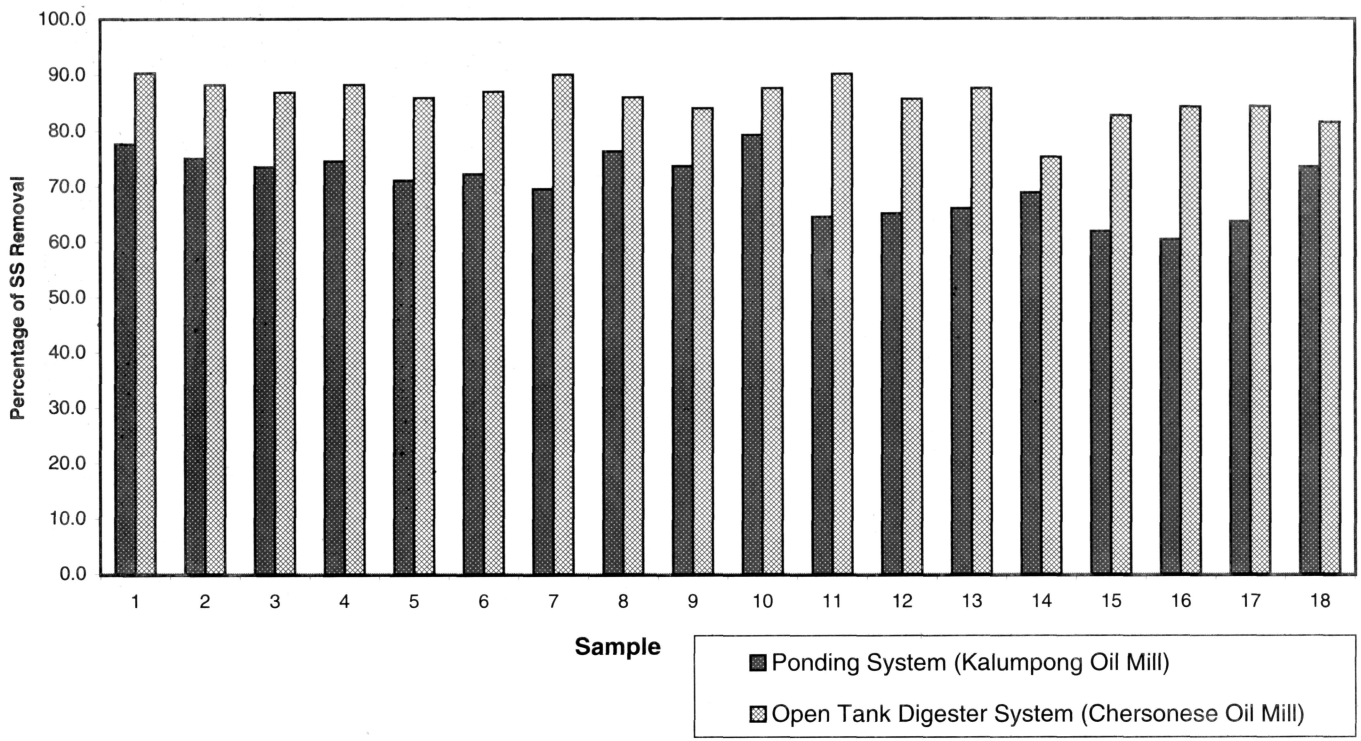

Figure 9: Percentages of Suspended Solids (SS) Removal

Table 8: Mean Concentration and Percentage Removal for Various Parameters in Palm Oil Effluent for Ponding System (Kalumpong Oil Mill, Guthrie Group)

Parameters	Ponding System			EQA Limits
	Inlet	Outlet	Percentage of Removal	
pH	5.43	7.09	-	5 - 9
BOD (mg/l)	82.18	74.72	10.1	100
COD (mg/l)	1320.9	67.5	94.4	1000
SS (mg/l)	98.94	29.33	70.3	400

* EQA – Environmental Quality Act

Table 9: Mean concentration and percentage removal for various parameters in palm oil effluent for Open Tank Digester (Chersonese Oil Mill, Golden Hope Plantation Bhd.)

Parameters	Open Tank Digester System			EQA Limits
	Inlet	Outlet	Percentage of Removal	
pH	6.28	7.98	-	5 - 9
BOD (mg/l)	35.93	28.18	21.5	100
COD (mg/l)	1653.1	41.2	97.4	1000
SS (mg/l)	171.83	23.28	85.9	400

* EQA – Environmental Quality Act

adjustment. An acidification reactor in the context of anaerobic treatment is one in which organic matter is converted to organic acids prior to conversion to methane. Therefore, after various treatment stages for both treatment the value of pH will be neutral or more alkaline. However, the pH values for treated POME were within the allowable range, 5-9.

The results showed that open tank digester system could remove as much as 86% suspended solids. Meanwhile, with ponding system about 70% suspended solids were removed from the palm oil mill effluent. High amount of suspended solids are caused by the cellulosic substance from palm fruits. From Figure 4, open tank digester system marked higher amount of suspended solid compared to ponding system after treatment. Generally, the treatment processes of each treatment systems do function differently and the effectiveness of POME treatment systems depend on this and maybe influenced by diverse reasons.

On the other hand, the biochemical oxygen demand in ponding system gives lower percentage of removal about 10% compared to open tank digester system that reduces about 21.5% BOD. Nonetheless, the percentage of BOD removal depicted very low removal after going through the treatment especially in ponding system. This might be due to the excessive solids accumulation in the anaerobic ponds which are difficult to be removed regularly. Hence, the problem affected the BOD removal efficiency. From the results obtained, it has been identified that the COD amount are much higher that BOD. The high COD/BOD ratio indicated the persistent of chemical present in the palm oil mill effluent. It is observed that for both treatment systems, the value COD decreased sharply. The sharp drop in amount of COD is mainly due to the effectiveness of the treatment processes in removing organic matter in palm oil mill effluent. The ponding system showed 94% COD removal and 97% COD removal for open tank digester system.

Conclusion

The results showed that ponding system (Kalumpong Oil Mill) and open tank digester system (Chersonese Oil Mill) could remove BOD, COD and suspended solids agreeably according to the limit set by EQA, equally efficient. The pH values for both treatment systems also between the allowable pH range by EQA. However the various treatment processes and stages use by ponding system and open tank digester system has suggested slight difference in the especially on removal efficiency for BOD, COD and suspended solids. The amount of BOD, COD and suspended solids are found to decrease more in open tank digester system. The effectiveness for palm oil mill effluent treatment systems depends on the treatment processes that provide different functions on the percentages removal of BOD, COD and suspended solids. Further investigation on nitrogen and phosphorus removal can be done to verify the effectiveness of treatment systems.

Acknowledgement

Kalumpong Oil Mill, Guthrie Group and Chersonese Oil Mill, Golden Hope Plantation, Kerian, Perak.

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