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# Biological treatment of anaerobically digested palm oil mill effluent (POME) using a Lab-Scale Sequencing Batch Reactor (SBR)

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ABSTRACT

The production of highly polluting palm oil mill effluent (POME) has resulted in serious environmental hazards. While anaerobic digestion is widely accepted as an effective method for the treatment of POME, anaerobic treatment of POME alone has difficulty meeting discharge limits due to the high organic strength of POME. Hence, subsequent post-treatment following aerobic treatment is vital to meet the discharge limits. The objective of the present study is to investigate the aerobic treatment of anaerobically digested POME by using a sequencing batch reactor (SBR). The SBR performance was assessed by measuring Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) removal as well as Sludge Volume Index (SVI). The operating pH and dissolved oxygen concentrations were found to be 8.25–9.14 and 1.5–6.4 mg/L, respectively, throughout the experiment. The experimental results demonstrate that MLVSS, OLR and sludge loading rate (SLR) play a significant role in the organic removal efficiency of SBR systems and therefore, further investigation on these parameters was conducted to attain optimum SBR performance. Maximum COD (95–96%), BOD (97–98%) and TSS (98–99%) removal efficiencies were achieved at optimum OLR, SLR and MLVSS concentration ranges of 1.8–4.2 kg COD/m$^3$ day, 2.5–4.6 kg TSS/m$^3$ day and 22,000–25,000 mg/L, respectively. The effluent quality remained stable and complied with the discharge limit. At the same time, the sludge showed good settling properties with average SVI of 65. It is envisaged that the SBR process could complement the anaerobic treatment to produce final treated effluent which meets the discharge limit.



## 1. Introduction

Over the last four decades, the palm oil industry has grown by leaps and bounds to become a very important agriculture based industry in Malaysia. Currently, Malaysia accounts for 51% of world palm oil production and 62% of world exports (MPOC, 2009). Concurrent to this huge amount of production, voluminous highly polluting wastewater referred as palm oil mill effluent (POME) is produced. Generally, 1 tonne of crude palm oil production requires 5–7.5 tonne of water; and more than 50% of the water will end up as POME (Ahmad et al., 2003). POME has been identified to be one of the major sources of water pollution due to its high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) concentrations. Hence, the government had enacted Environmental Quality Acts (EQA) in 1978 and set parameter limits for the discharge of POME into the environment as shown in Table 6.

A wide range of approaches for the treatment of POME have been developed to alleviate the pollution problems caused by the palm oil industry. The most frequently used method is biological treatment, which consist of anaerobic and facultative pond systems. While anaerobic pond is one of the most common treatments adopted in Malaysia to treat highly concentrated POME, anaerobic treatment of POME alone could hardly produce effluents to a level complying with the DOE discharge limit. The reported results shown in Tables 1 and 2 clearly indicated that the anaerobically digested POME still contains high COD and BOD concentrations. It is essential to subject the effluents to an appropriate post-treatment before discharging in order to meet regulatory limits. Since anaerobically digested POME is amenable to aerobic treatment based on its physical composition, primary treatment of POME through anaerobic treatment and subsequent post-treatment of aerobic treatment appears to be the most techno-economically viable approach.

There are many examples of anaerobic–aerobic treatment in which anaerobic processes provide partial removal of organic matter before further treatment with aerobic processes due to the

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**Table 1**
Aerobic treatment of anaerobically digested POME and palm oil refinery effluent (PORE).

| Parameters | Vijayaraghavan et al. (2007) | Chin et al. (1987) | Fun et al. (2007) |
|---|---|---|---|
| System[a] | ASR | SBR | SBR |
| Type of ww[b] | POME | PORE | POME |
| Influent COD (mg/L) | 1000–5000 | 896–980 | – |
| Influent BOD (mg/L) | – | 164–289 | – |
| COD removal (%) | 27–83 | 50–31 | 82 |
| BOD removal (%) | – | 50–70 | – |
| TSS removal (%) | | – | 62 |
| HRT[c] (h or d) | 24–36 h | 8 h | 3 d |
| MLSS[d] (mg/L) | 3900 | – | 2500–4000 |
| DO[e] (mg/L) | 1.8–2.2 | 2 | – |
| T[f] (°C) | – | 40–44 | – |
| pH | 7–8.5 | – | – |

[a] System: SBR, sequencing batch reactor; ASR, activated sludge reactor.
[b] Type of wastewater (ww): POME, palm oil mill effluent; PORE, palm oil refinery effluent.
[c] HRT, Hydraulic retention time: h, hour; d, day.
[d] MLSS, mixed liquor suspended solid.
[e] DO, dissolved oxygen.
[f] T, temperature.

relatively high strength of many industrial wastewaters. Anaerobic–aerobic processes using reactors in series are feasible for treating municipal and high organic strength industrial wastewaters which resulting in higher treatment efficiency, lower energy requirements and less sludge production (Castillo et al., 1997; Jenícek et al., 1999; Del Pozo and Diez, 2003; Garbossa et al., 2005). POME is also reported to have been treated successfully by anaerobic–aerobic ponding systems (Ma and Ong, 1988). Some palm oil mills employ conventional anaerobic–aerobic systems which are comprised of open tank digesters and extended aeration systems in POME treatment. In this system, POME is treated in a two phase anaerobic digestion process followed by extended aeration in a pond with hydraulic retention time (HRT) of about 40 days. If it is properly operated and maintained, the treated effluent is able to meet the discharge limit (Ma, 1993). However, these conventional anaerobic–aerobic treatment systems frequently encounter problems associated to their large space requirement, long HRT, low organic loading rate (OLR) and thus could hardly keep pace with growing generation of effluent by the mills.

In order to reduce the land area required by aerobic pond, Vijayaraghavan et al. (2007) proposed to use an activated sludge reactor as post-treatment after an anaerobic digestion process. It was found that the COD removal efficiency declined from 83 to 42% and 57% to 27% at HRT of 36 h and 24 h, respectively, when the influent concentrations increased from 1000 to 5000 mg/L. In addition, the effluent failed to meet the discharge standard. Activated sludge system appears to be one of the most effective aerobic treatment systems, however is the least used by palm oil mills due to its higher operation cost. An overview pertaining to the performance of aerobic treatment of anaerobically digested POME is summarized in Table 1.

In recent years, sequencing batch reactor (SBR) has been employed as an effective technology for industrial and municipal wastewater treatment, because of its simple single tank configuration and high efficiency in BOD and SS removal (89–98% and 85–97%, respectively) (Mahvi, 2008). SBR is an improved version of activated sludge system and the term SBR stems from the sequence of its steps which occur within the same vessel: filling, aeration, settling and decantation. Its design is simple yet produces high quality effluent, since the system acts as an equalization tank, reactor as well as a clarifier. The flexibility in operation reduces costs without sacrificing effluent quality.

SBR has been proved to be a cost effective treatment system for Palm Oil Refinery Effluent (PORE). PORE possess high organic content with COD values ranging from 896 to 980 mg/L and BOD values ranging from 164 to 289 mg/L (Chin et al., 1987). The treated effluent has a consistent BOD concentration of below 50 mg/L (Ma, 1993). Hence, it shows great potential to treat anaerobically digested POME. However, very few studies have been conducted on the post-treatment of anaerobically digested POME using SBR. Recently, there was a study carried out by Fun et al. (2007) using a bench scale SBR to further treat the anaerobically digested effluent from an anaerobic pond (Table 1). Promising results was achieved, with highest percentage removal of 62% for TSS, and 82% for COD at mixed liquor suspended solid (MLSS) level of 2500–4000 mg/L and HRT as long as 3 days. Nevertheless, the effluent is still unable to satisfy the discharge limit.

In fact, there is scarcity of information on the assessment of the efficiency of post-treatment on anaerobically digested POME by utilizing aerobic processes to produce final effluent which conforming to the regulatory standards. Thus, the objective of this study is to investigate the aerobic treatment of anaerobically digested POME by using SBR to produce high quality effluent which complies with the effluent discharge standard. Factors affecting the performance of the SBR with regards to BOD, COD and total suspended solids (TSS) removal efficiencies were studied.

## 2. Material and methods

### *2.1. Wastewater preparation and preservation*

Anaerobically digested POME using closed-type anaerobic digester system was collected from West Oil Mill, Carey Island, Malaysia. The characteristics of the anaerobically digested POME were analyzed and summarized in Table 2. In order to prevent the wastewater from undergoing biodegradation due to microbial

**Table 2**
Characteristic of anaerobically digested POME obtained in this study and other literature.

| Parameters[a] | This study | | Ho and Tan (1989) | Phang and Ong (1988) | Vijayaraghavan et al. (2007) |
|---|---|---|---|---|---|
| | Average concentrations | Range | Average concentrations | Average concentrations | Average concentrations |
| pH | 7.4 | 7.3–7.5 | 7.1 | 7.24 | 7.8 |
| BOD[b] | 1355 | 981–2332 | 655 | 1938 | – |
| COD | 13,650 | 11000–18650 | 5430 | 20,314 | 1372 |
| TS | 19,370 | 15470–21100 | 8300 | 20,889 | – |
| TSS | 12,750 | 11050–15100 | 3100 | 14,686 | 512 |
| TN | 320 | 240–462 | – | – | 134 |

[a] All parameters in mg/L except pH.
[b] Sample incubated for 3 days at 30 °C.