Anaerobic Treatment of Palm Oil Mill Effluent (POME) by Reversible Flow Anaerobic Baffled Reactor (RABR)

可逆流入型嫌気性バッフルドリアクターによるパームオイル廃液の高速処理

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Introduction

In year 2000, Malaysia had produced 10.8 million tons of crude palm oil (CPO). The extraction process during production of CPO, however also resulted in discharged voluminous amount of highly polluting palm oil mill effluent (POME). Typically, the amount of POME generated accounts for 3.5m^3 per ton of CPO. POME contains 55,000-110000mgl^{-1} of unfiltered COD. In terms of organic load it is equivalent to 43 million population equivalents (p.e), approximately 2 times of Malaysian population. Moreover, POME is mainly treated in anaerobic lagoons, producing an estimated 6.2 million p.e (30 % of Malaysia population) of green house gas that is released to atmosphere. The potential electricity could be generated from POME is estimated at 2000MWH or 3.6 % of Malaysia electricity consumption. The aim of this study is to develop high rate anaerobic treatment of palm oil mill effluent (POME) for energy recovery and suppression of global warming.

Reversible Flow Anaerobic Baffled Reactor (RABR)

RABR is made of three different size PVC cylinders. The inner and outer cylinders are used for water jacket. A baffle is fixed to the wall between inner and middle cylinders so that the reactor resembles an Anaerobic Baffled Reactor (ABR). A total of 5 equal-volume compartments are installed inside the reactor with undivided gas space on the top. During the period of operation, the influent is fed from the feeding compartment and flow upward under a baffle of the same compartment, before passes into the next (second) compartment through an open slit. The process is repeated until the exit compartment.

Materials and Methods

A schematic diagram of 20 liters working volume lab-scale RABR is given in Fig.1. Two RABRs were operated in parallel at 35°C and 55°C. Both of reactors were inoculated with approximately 300gVSS of inoculum, resulting in initial VSS concentration of 15$g.l^{-1}$. The mesophilic granular sludge from full-scale UASB plant treating food processing wastewater was used as inoculum for the mesophilic RABR. Thermophilic sludge from laboratory scale reactor treating diary milk wastewater was used as inoculum for the thermophilic reactor. Raw POME was transported from Malaysia by air cargo. POME contains approximately 110000mgl^{-1} of unfiltered COD, which particulate COD accounts for 60% of the total COD. Some characteristics of POME are given in Table 1. Carbohydrate, protein and lipid are three major constituents in POME, accounting for 22.3%, 26.0% and 26.8% of the total COD, respectively.

Substrate was prepared by diluting raw POME with tap water. Sodium bicarbonate (0.33g$NaHCO_3$ per g COD of substrate) was added to neutralize the substrates. Sequence controller was used to change the feeding and effluent compartment in periodical manner. The feed flow was reversed just after the feeding-compartment receives substrates for 2HRTs. Prior to switch to reversed flow, the middle compartment was fed for 1HRT to prevent break through of the substrates. The effluent samples were obtained after 1HRT interval between two reversals of flow. At this time, the samples were assumed to be representative of the overall performance.

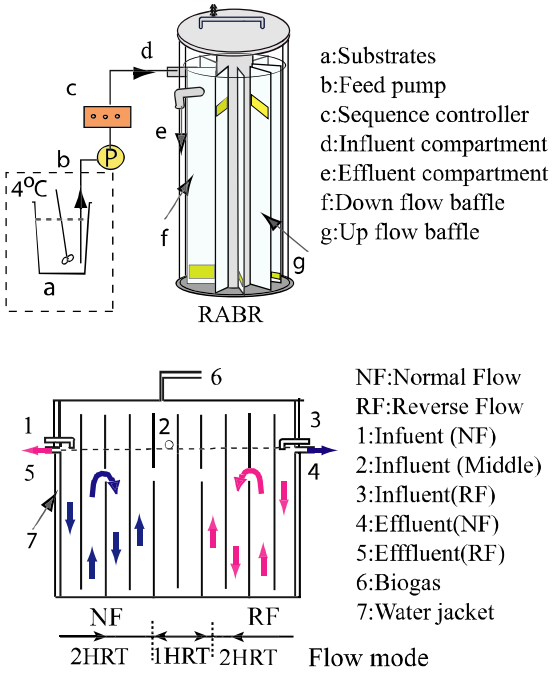

Fig.1:Schematic flow diagram of RABR

Table.1 Main characteristic of raw POME used as substrates in this study

Parameter	Raw POME
pH	4.3
Total COD (mg/l)	110000
Soluble COD (mg/l)	42900
Lipid (as mgCOD/l)	29500
Carbohydrate (as mg/l)	24600
Protein (as mg/l)	28600
TSS (mg/l)	35800
VSS (mg/l)	32200
TKN (mg/l)	2130
C/N ratio	20

Keyword: Mesophilic; Thermophilic; POME; Reversible flow; Anaerobic Baffled Reactor.
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Results and Discussion

The COD loading was increased step wise from 1 to 16 kgCOD.m^{-3}.day^{-1} by varying the influent strength from 3000-8000 mg.l^{-1} or increasing flow rates. During this period of operation biogas production increased corresponding to increases in loading, whilst the percentage of methane gas gradually decreased from an initial value of 65% to about 60% in both reactors (data not shown). At a loading rate of 16 kgCOD.m^{-3}.day^{-1}, the HRT was maintained at 12 hrs. At this period, the TCOD and SCOD removal efficiency was 80% and 78%, respectively in mesophilic reactor. In contrast, the TCOD and SCOD removal efficiency was 78% and 85%, respectively in thermophilic reactor. Higher SS concentration was always observed in the final effluent of thermophilic reactor. Average SS removal efficiency (data not shown) was smaller in thermophilic (67%) compared to that of mesophilic (86%) reactor. However, the undegraded SS in the influent of the mesophilic reactor tends to accumulate inside the reactor as floating scum rather than being degraded or carried over with effluent. The profile data along compartment clearly showed that acetate and propionate was rather high in the first three compartment of mesophilic reactor. In contrast, for thermophilic reactor, only small amount of VFA was detected in the first compartment. The methane recovery also was found to be greater in thermophilic (60%) than in mesophilic (50%), data not shown. This might be due the fact that at higher temperature the biodegradation of solid proceeds more rapidly, subsequently produced more methane gas. High lipid removal of more than 80% was also observed in both reactors.

Summary

The results show that RABR achieved a satisfactory treatment of POME. The thermophilic reactor was better than mesophilic one, with respect to soluble COD, VFA and methane recovery. Problem related to formation of floating scum was more prominent in the mesophilic RABR, rather than in the thermophilic RABR. Thermophilic reactor exhibited better performance at a loading of 16kgCOD.m^{-3}.day^{-1} at a HRT of 12 hrs. This loading rate corresponds to approximately 6.5 times as high as present conventional anaerobic digester and 16 times as high as widely used anaerobic lagoon system.

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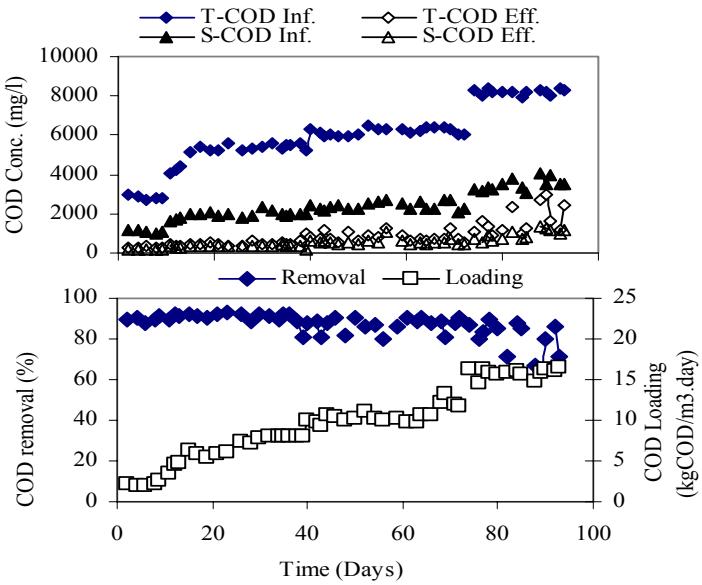

Fig.2 &3 COD loading, removal and concentration (35°C)

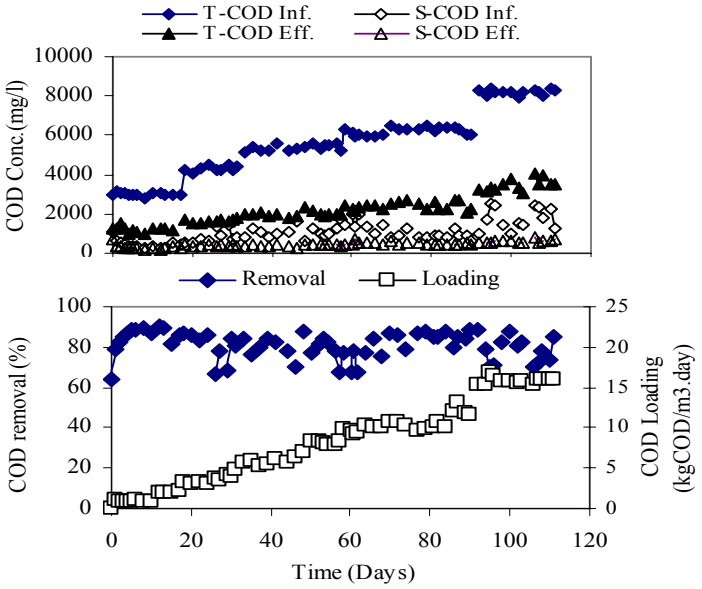

Fig.4&5 COD loading, removal and concentration (55°C)

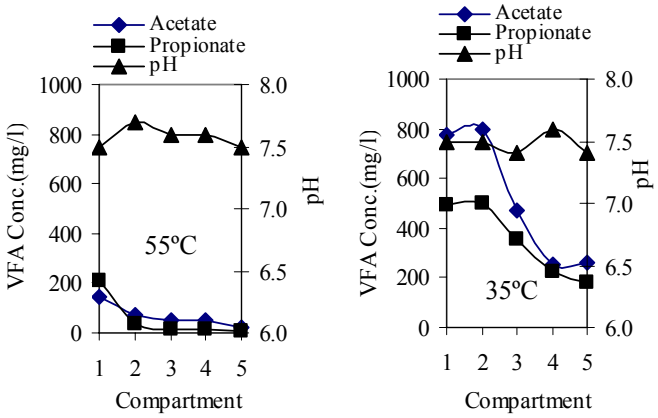

Fig.6 Major VFA and pH profile in each compartment