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ANAEROBIC FLUIDIZED BED REACTOR (AFBR) FOR THE TREATMENT OF HIGH SOLID CONTENT AGRO-INDUSTRIAL WASTEWATER

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Abstract – Palm oil mill effluent (POME) is a high strength agro-industrial wastewater that contains significant amount of organic suspended solids. These solids reduce plant efficiency and account for additional maintenance of fixed bed digesters. An anaerobic fluidized bed reactor was studied to evaluate the performance of the system to treat solids from the POME. The hydraulic retention time (HRT) was reduced step wise from 24 hr to 4 hr, which resulted in volumetric loading rates of 4.0 kg COD/m^3.d to 13.8 kg COD/m^3.d, respectively. The maximum TSS removal rates varied in the range of 68% - 89%. The AFBR showed promising performance without exhibiting any problem pertaining to the solids in the wastewater. The AFBR exhibited low sludge production with sludge volume indices (SVI) of between 11 L/mg and 35 L/mg. The low SVI indicates fast settleability and self-compressibility of the digested solid particles in POME. The study showed the superiority of AFBR over the other treatment processes in treating industrial wastewater that contains significant portion of solids.

INTRODUCTION

Depending on the effluent characteristics, industrial wastewaters are treated by physical, chemical and biological unit processes (Qasim, 1999; Ma, 1992; Tchobanoglous and Burton, 1991; Sutton and Mishra, 1990). Generally, combinations of two or more unit processes are required to achieve a satisfactory level of removal efficiency. Anaerobic biological treatment is widely accepted in the agro-industries, mainly due to less energy requirement, capability to handle high pollution loading rate, production of bio-gas as by-product, etc. (Mathiot *et al*., 1992).

Most of the palm oil industries in Malaysia use conventional, land consuming and inefficient pond treatment system (Ma *et al*., 1993). The pond systems are designed depending on few parameters, such as hydraulic retention time (HRT), solids residence time (SRT), influent and effluent concentrations, sludge age, etc. Most of these ponds are anaerobic and others are either facultative or aerobic. Large surface areas are required to treat the wastewater satisfactorily, with classical pond systems. These systems are unable to treat the wastewaters to the satisfactory level and thus partially treated effluent from the ponds adds pollutants to the surface waters. Lately few types of closed tank anaerobic digesters are being installed in some of the big industries. One of the major problems with other treatment system is to handle the solids available in POME. Thus, there was a need to find out a suitable treatment system, which is cheaper but efficient and can tackle the problem of having solids in the wastewaters.

Up-flow anaerobic sludge blanket, anaerobic filters, anaerobic expanded bed reactor and anaerobic fluidised bed reactor are mostly preferred for high strength wastewater treatment (Idris, 1993). AFBR provides longer solid residence time (SRT), which is required for efficient and stable operation of the system. Higher SRT and shorter HRT are the important prerequisites for an economical treatment system (Switzenbaum, 1983). Recently, palm oil

industries in Malaysia are introducing anaerobic digesters into their treatment facilities, but no AFBR is, so far, reported to be installed in any industry. Besides, no large-scale study is undertaken so far to evaluate the feasibility of anaerobic fluidized bed reactors for the treatment of palm oil mill effluent (POME), let alone full-scale implementation. The main objective of this paper is to report the performance of an AFBR for the treatment of industrial wastewater in the context of suspended solid removal performance.

METHODOLOGY

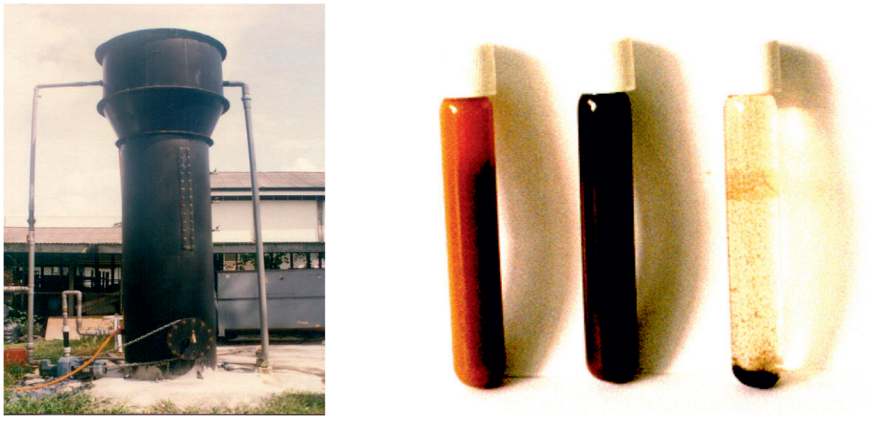
The AFBR (Figure 1) was partially filled with sand, having uniformity coefficient (C_u) of 1.6 and gradation coefficient (C_c) of 1.09. The concentrated POME was diluted to provide uniform organic load ranging between 1.8 and 2.0 kg COD/m^3.day during the start-up period. As BOD does not represent the total organic content in the substrate (Orhon *et al*., 1998), the chemical oxygen demand (COD) was monitored to define steady states and to determine the kinetic coefficients.

It was assumed that the system had attained steady state when difference among COD removal rates for three consecutive tests varied within 5 %. The substrate (POME) consisted of about 90-95 % of water, 4.5-9 % of solids (approximately half in solution and the rest in suspension), and 0.5-1 % residual and grease. Palm oil mill effluent (POME) has very high BOD (25,000-30,000 mg/L) and COD (50,000-60,000 mg/l). The reactor was operated under ambient temperature ranging between 25-31 ^oC (mesophilic condition) with pH around 7. The samples were collected daily and analysed according to Standard Methods (APHA, 2005).

RESULTS AND DISCUSSION

According to Hobson and Wheatly (1993) most digester systems are self-buffering at around pH 7. Therefore, pH of the pilot plant AFBR was maintained around 7. Chemical oxygen demand (COD) was considered as the main controlling parameter to define steady states and overall reactor performance. COD was monitored almost daily and the plot (Figure 2) was more representative to the digester activity. The Maximum COD removal rate achieved at steady state was 85% and the minimum was 65.2% (Figure 2). These were achieved at HRT of 12 and 4 hour under OLR of 4.0 and 13.8 kg COD/m^3.d, respectively. Figure 3 shows the COD removal plotted against loading rate. The result showed that, COD removal rate decreased steadily with increasing loading rate. This observation was in agreement with the trend reported by Chen *et al.* (1985).

Figure 2 shows the reactor performance in terms of total suspended solids (TSS) removal. TSS removal rate throughout the study was promising. Maximum TSS removal rate achieved was 89% at an HRT of 12 hour. This removal rate was achieved at an OLR of 1.92 kg TSS/m^3.d. TSS removal efficiency was declining with the increase in OLR but the decrement was less at loading rates higher than 4 kgTSS/m^3.d. Despite promising settling characteristic of the effluent, there was always some permanent colour in the treated effluent. Kutty *et al*. (2019); Chaijak *et al.* (2017); Ng (2016) and Neoh *et al.* (2013) also observed similar problems of having colour in POME. This colour could not be removed



(a) AFBR (b) Raw, Treated and Settled POME

Fig. 1. The anaerobic fluidised bed reactor (AFBR) and the wastewater (POME)

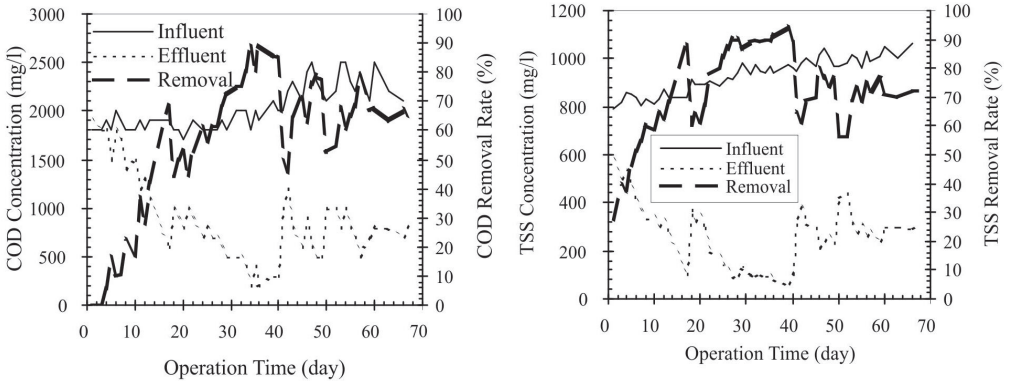


Fig. 2. Performance of the AFBR in removing COD and TSS from wastewater

substantially even by ultra-membrane filtration Wong *et al.* (2002) and Khor (1998).

CONCLUSION

A pilot scale anaerobic fluidised bed reactor (AFBR) was studied for treatment of agro-industrial wastewater, which was diluted palm oil mill effluent (POME) that contains significant amount of solids. Special attention was given to evaluate the performance of the reactor in removal of solids. Chemical oxygen demand (COD) of the substrate was considered as the main monitoring parameter to define the steady states and overall reactor performance. The COD loading rates were varied between 4 and 13.8 kg COD/m^3.d. The minimum and maximum TSS removal rates were 68% and 89% at hydraulic retention time (HRT) of 4 and 12 hours, respectively. The system ran well without any clogging problems. The study showed that the AFBR has the potentiality to treat industrial wastewater that contains significant portion of coarse and fine organic solids.

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