Chapter 16

Anaerobic treatment of distillery and brewery wastewaters

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Introduction

Anaerobic treatment has preference over aerobic processes for high strength wastewaters because of comparatively low sludge production and low energy consumption. One of the main setbacks of anaerobic systems is the relatively long biomass retention time (or solids retention time, SRT) required for effective treatment, due to the relative slow growing methane-producing bacteria. In conventional anaerobic systems, hydraulic retention time (HRT) within the system has to be maintained long enough in order to ensure long SRT, thus necessitating the need for relatively large reactor systems. However, with the advent of high rate reactor systems which are capable of separating HRT and SRT, anaerobic processes are presently popular choice for the treatment of intermediate to high strength wastewaters.

A GRAnular Bed Baffled Reactor (GRABBR), shown schematically in Figure 1, is one of the high rate anaerobic wastewater treatment systems which, due to its compartmentalised design, encourages plug flow, phase separation and minimises short-circuiting (Barber and

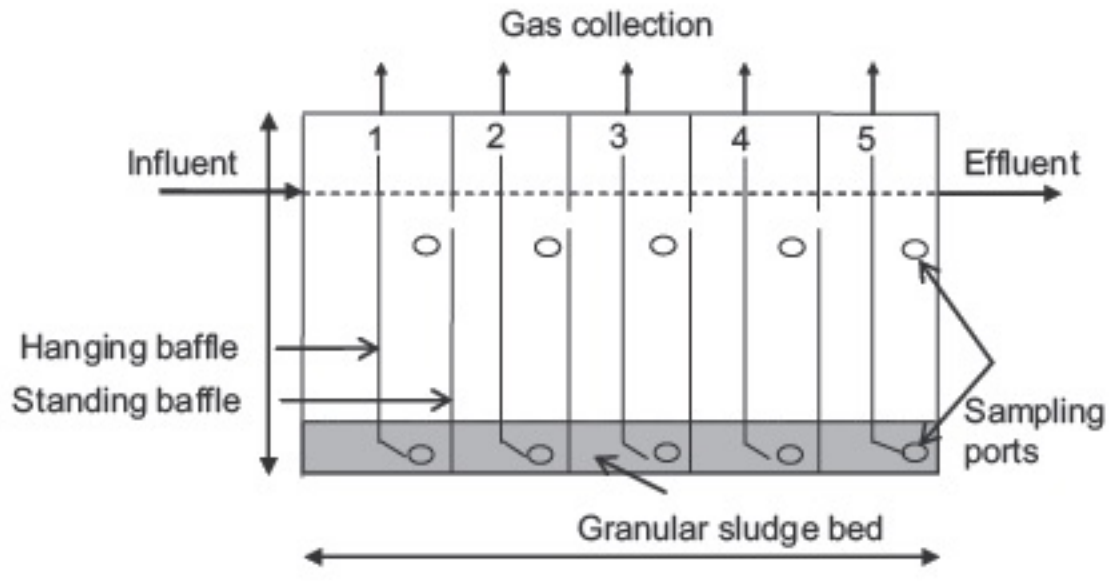

Figure 1. Schematic of a 5-compartment GRABBR

Stuckey 1999; Balch and Akunna 2003a,b). The importance of phase separation (i.e. separation of acidogenesis and methanogenesis process stages) has been found to be suitable for the treatment of complex substrates in order to ensure process stability (Pohland and Ghosh 1971; Anderson *et al.* 1994; Shin *et al.* 2001). Each compartment of the GRABBR is itself a separate treatment unit and completely mixed. This paper discusses the performance of GRABBR when used to assess the treatability of distillery and brewery wastewaters. These wastewaters are also characterised by relatively high solids content, which may limit the type of system suitable for their treatment.

Two different GRABBRs were used for the study. The aim was not to compare their relative performances but to evaluate the treatability of both wastewaters and to identify the characteristics of the GRABBR system in terms of phase separation, effects of seed sludge bed size, stability at various loading rates, COD removal and biomass washout.

Treatment of distillery wastewater

This study was carried out with a 35-litre GRABBR divided into 10 equal compartments, maintained at constant temperature of 37°C and seeded to approximately 13% of the working volume with granular sludge obtained from a mesophilic UASB reactor treating papermill wastewater. The raw wastewater composed of COD (16600-58000 mg/l), suspended solids (232-7810 mg/l), volatile suspended solids (200-7340 mg/l), Total Kjeldahl Nitrogen, TKN (500-1200 mg/l), and pH (3-4). The reactor was fed with diluted wastewater at a constant feed strength of 9500 mg/L (total) COD, at different retention times to obtain organic loading rates (OLRs) of 0.99, 1.33, 2.37 and 4.75. The raw wastewater was diluted to the desired strength with tap water and the pH was corrected to about 7.5 using 10M NaOH. Detailed experimental methodology can be found in Akunna and Clark (2000).

Up to 90% COD removal was obtained at relatively low OLR as shown in Table 1. The maximum specific gas production during the studies was approximately 0.3 $m^3CH_4/COD_{removed}$. High influent solids hindered the application of higher OLR. Raw wastewater pre-treatment for solids reduction may be necessary in order to operate at higher OLR.

Table 1. COD removal efficiencies at different organic loading rates (distillery wastewater)

OLR (kg COD/m³.d)	*COD_{in} (mg/l)*	*COD removal (%)*
0.99	9500	87
1.33	9500	91
2.37	9500	92
4.75	9500	80

Treatment of brewery wastewater

The laboratory study was carried out with a 10 litre capacity 5-compartment GRABBR. Two investigations were conducted, the first with mainly brewery wastewater and the other enriched with excess yeast. Table 2 shows the wastewater characteristics. Excess yeast contains relatively high amounts of sulphates which, when treated anaerobically can lead to process failure due to sulphide toxicity.

Tap water was used, when necessary, to dilute the raw wastewaters to the required strength. pH was adjusted to between 7.2 and 7.5 by adding $NaHCO_3$ and NH_4HCO_3 solutions. No correction was made when the pH values of the wastewaters were greater than 7.2. Detailed experimental set-up can be found in Baloch *et al.* (2006).

Table 3 shows the overall performance in terms of COD removal in both studies and Figure 2 shows the profile of COD concentration within the system during the first study. For both wastewaters, influent COD concentrations were variable and increases in OLR were achieved by varying both influent COD concentrations and HRT. From Table 3 it can be seen that with the brewery wastewater the GRABBR achieved

91% COD removal at a maximum OLR of 15 kgCOD/m³.day. For the yeast enriched brewery wastewater, the GRABBR achieved 75% COD removal for the same OLR of 15 kgCOD/m³.day. For the former, the removal efficiency fell sharply to 60% when the OLR was raised to 20 kgCOD/m³.day.

Table 2. Types and composition brewery wastewaters used in the study

Parameter	*Concentration (mg/l)*[a]	
	Brewery effluent	*Yeast-enriched wastewater*
COD	3000 - 6000	50000-110000
Suspended solids	50 - 1000	2000 -3000
TKN	24 - 200	500-10000
SO_4^{2-}	35	160
pH	5 - 11	8.3

[a] All parameters are in mg/l except pH

Table 3. COD removal efficiencies under different loading conditions

Yeast-enriched brewery wastewater		*Brewery wastewater (Average values)*	
OLR (kg COD/ m³.day)	*COD removal (%)*	*OLR (kg COD/ m³.day)*	*COD removal (%)*
3	88	1	97
5	91	2.5	93
10	90	5	96
15	75	10	90
20	60	15	91

Figure 2 demonstrates some of the benefits of GRABBR – plug flow and phase separation. The stability of the system was enhanced by the fact that as the OLR was increased; downstream compartments of the reactor were put to more effective use and vice versa. Thus, the GRABBR is capable of accommodating a wide range of wastewater production rates (and thus wide variation of OLRs) without incurring increased operational difficulties and costs. Gas production rates in both studies were similar, ranging from 0.3-0.38 $m^3CH_4/COD_{removed}$.

Conclusions

This study has shown that distillery and brewery wastes are amenable to anaerobic digestion. The benefits of GRABBR have also been demonstrated by the study. At relatively low OLR, GRABBR operates as one completely mixed unit utilising only the inlet compartment of the system. More compartments within the system contribute to treatment as OLR is increased. At relatively high OLR, stability of the system is ensured by the self-creation of different phases within the reactor, with mainly acid production in the inlet compartments and methane production in the downstream compartments. The reactor is thus capable of accommodating effluents with variable production rates and characteristics.

The study also showed that the GRABBR can treat yeast-enriched wastewater. The

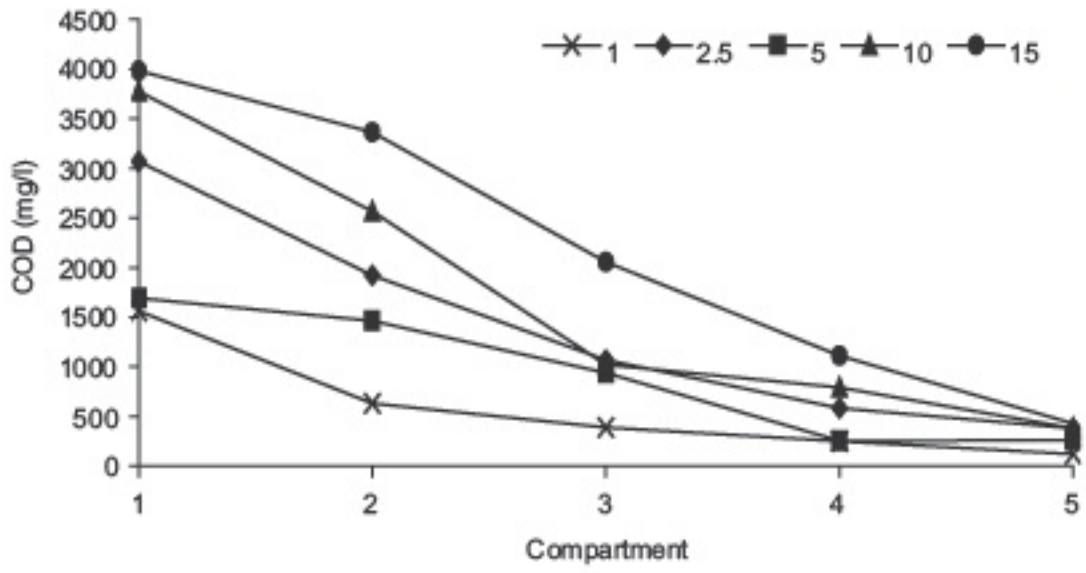

Figure 2. COD profile with the GRABBR when treating brewery wastewater

compartmentalised nature of the system enables sulphate in the yeast to be reduced to sulphide at the inlet compartments in order to reduce sulphide inhibition of methane-producing bacteria inhabiting at the outlet compartments.

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References

Akunna, J. C. and Clark M. (2000) Performance of a granular-bed anaerobic baffled reactor (GRABBR) treating whisky distillery wastewater. *Bioresour. Technol.* **74**, 257-261.

Anderson, G. K., Kasapgil, B. and Ince, O. (1994) Microbiological study of two-stage anaerobic digestion during start-up. *Water Res.* **28**, 2383-2392.

Baloch, M. I. and Akunna, J. C. (2003a) Granular Bed Baffled Reactor (Grabbr): Solution to a Two-Phase Anaerobic Digestion system. *J. Environ. Eng.* ASCE, November 2003, 1015-1021.

Baloch, M. I and Akunna, J. C. (2003b) Effect of Rapid Hydraulic Shock Loads on the performance of Granular Bed Baffled Reactor. *Environ. Technol.* **24**, 361-368.

Baloch, M. I., Akunna, J. C. and Collier, P. J. (2006) The performance of a phase separated granular bed baffled reactor treating brewery wastewater. *Bioresour. Technol.* **98**, 1849-1855.

Barber, W. P. and Stuckey, D. C. (1999) The use of anaerobic baffled reactor for wastewater treatment: a review. *Water Res.* **33**, 1559-1578.

Pohland, F. G. and Ghosh, S. (1971) Developments in anaerobic treatment processes. *Biotechnol. Bioeng.* Symp., **2**, 85-106.