STUDY OF DIFFERENT SUPPORTS IN A SBBR.

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ABSTRACT

Four sequencing batch biofilm reactors (SBBR) with different supports were used to select the most suitable one for SBBR operation. High efficiencies of organic matter and nitrogen removal were obtained (94% and 80% respectively), up to a loading of 1.2 kg COD/m^3·d and 0.19 kg N-NH_4^+/m^3·d. The thermodynamic characterisation of the supports indicates that real effluent interaction (instead of water) must be taken into account, regarding initial bioadhesion. The results demonstrate that the studied plastic supports are appropriate for the biomass adhesion and that the biofilm accumulation on each support exhibited different profiles.

KEYWORDS

Biofilm, SBBR, Nitrogen removal, Support, Surface energy.

INTRODUCTION

Attached growth systems are a known treatment process for wastewater nitrification and denitrification. Sequencing batch biofilm reactor (SBBR) combines the reliability of conventional sequencing batch reactors with the benefits of biofilm systems (Jaar and Wilderer 1992). The use of plastic elements as biofilm development supports are becoming increasingly common. The interaction between surface properties of bacteria and support greatly influences the bioadhesion phenomenon. The free energy interaction (ΔG_{SW}^{TOT}) between a surface and water is the standard measure of the hydrophobic interaction that can be established between the surface (support or biomass) and water molecules. The free energy is related to the individual surfaces tension components. Materials having low surface free energies of interaction with bacteria are more favourable to biofilms' stability (Teixeira and Oliveira, 1998).

The present work concerns the characterisation of support materials in order to select the most appropriate one for SBBR operation.

METHODS

Experimental set-up

Reactors operation: Four SBBRs with working volumes between 2 and 2.5 L filled with different supports were tested (Table 1). The reactor volume occupied by support material was about 40%. In the first operation period (days 0-23) the wastewater was collected in a brewery industry after an anaerobic pre-treatment. At day 23 a synthetic medium with acetate and ammonium was used (Table 2). The duration of the operation cycle was 6.2 hours (Anoxic phase: 1.7 h; Aerobic phase: 2.5 h; Settling phase: 1.90 h and Discharge phase: 10 min). The reactor was continuously fed only during the anoxic phase. The temperature of operation was 20°C. The SBBRs were inoculated with biomass from the nitrification/denitrification system used at the brewery to treat the anaerobic effluent.

Table 1. Characteristics of supports used in each reactor

Support designation	Material	Specific surface area (m^2/m^3)	Reactor
Leca	Clay	-----	I
DupUM	PE [a)]	550	II
Bioflow30	PP [b)] – recycle	320	III
Biolox10	PE [a)]-recycle	640	IV

a) Polyethylene; b) Polypropylene

Table 2. Influent composition

Composition (mg/L)	Period I (0-22)	Period II (23-127)	Period III (127-145)
COD_T	416-180	500	750
COD_S	240-90	500	750
$N\text{-}NH_4^+$	36-30	80	120
$NaHCO_3$	----	250	375
Traces* (ml/l)	-----	0.5	0.5

*According to Vishniac and Santer (1957)

Activity assays: The nitrifying activity was determined in batch respirometric assays using a Biological Oxygen Monitor (BOM) connected to a PC with a data acquisition program. Activity tests were done at 20°C and pH was fixed at 7.6 using a phosphate buffer (1.43 g KH_2PO_4/L and 7.47 g K_2HPO_4/L) adjusted with NaOH 10 N. Initial ammonia/nitrite concentrations were 20 mg N/l, which avoids substrate limitation during the experimental period. Denitrifying activity tests were carried out in flasks with a useful volume of 50 mL. These flasks were agitated at 150 rpm and at 20°C. The buffer used was the same used in nitrifying activity assays, with the initial nitrate and acetate concentrations being 50 mg $N\text{-}NO_3^-$/L and 150 mg C-AcNa/L, respectively.

Support characterisation: The thermodynamic characterisation of the supports was carried out by two techniques: thin-layer wicking for the clay support and contact angle measurements for the plastic supports as described by Teixeira *et al.* (1998). Surface free energy and surface tension components were calculated by using the method of van Oss *et al.* (1988). Contact angles were measured using the sessile drop method at 20°C with destilled water, formamide and 1-bromonaphthalene. The measurements were carried out in a standard contact angle apparatus (Kruss-GmH, Hamburg). The surface tensions components of the biomass were determined based on the contact angle measurements on agar plates covered with biomass. The thin layer wicking method was employed for Leca support characterisation using glass plates of finely divided powdered support. The probe liquids were *n*-decane, water and formamide and the experiments were carried out at 20°C.

Analytical methods

Ammonia, nitrite, nitrate, COD and Volatile Suspended Solids (VSS) were determined as proposed in Standard Methods (APHA, 1995). Oxygen concentrations were measured with a dissolved oxygen meter YSI, model 5000. The biofilm accumulation on plastic supports was estimated as dry weight measurements (Lazarova *et al.*, 1994).

RESULTS AND DISCUSSION

During the first period (days 0-22) the reactors were fed with the industrial wastewater The efficiencies of organic matter removal and nitrification were high (78 and 98%, respectively), but denitrification was null. These efficiencies were similar to those obtained in the nitrification/denitrification reactor at the brewery industry. A synthetic medium was used after day 23 to favour the growth of denitrifying biomass. Heterotrophic, ammonia oxidising and denitrifying activities decreased during the first period of operation but increased when the synthetic medium was employed. Along the period II and III, the efficiency of the organic matter removal increased up to 94% at a COD loading of 0.8 and 1.2 kg $COD/m^3\cdot d$, while the efficiency of the nitrogen removal was 80% at a nitrogen loading of 0.13 and 0.19 kg $N\text{-}NH_4^+/m^3\cdot d$. The specific activities were 83 $N\text{-}NH_4^+/gVSS\cdot d$, 1000 mg $N\text{-}NO_3^-/gVSS\cdot d$ and 2170 mg $COD/gVSS\cdot d$.

The apolar (γ_s^{LW}) and polar (γ_s^{AB}) surfaces tension parameters for each support material and for biomass are given in Table 3, where γ_s^{+} and γ_s^{-} are electron acceptor and electron donor parameters of the polar component of surface tension, respectively.

Table 3. Experimental contact angles (°), surface tension components of support materials determined by (a) contact angles measurements and (b) thin layer wicking, in mJ m^{-2}, at 20°C

Support	Contac angle (°)			Free energy components (mJ m^{-2})				
	W	F	BN	γ_s^{LW}	γ_s^{-}	γ_s^{+}	γ_s^{AB}	γ_s^{TOT}
Biomass[a)]	36.71 ± 2.68	38.64 ± 1.92	23.48 ± 2.58	40.80	47.00	0.05	3.07	43.87
Bioflow30[a)]	87.98 ± 4.95	80.70 ± 3.94	24.60 ± 1.42	40.46	11.18	0.00	0.00	40.46
Biolox10[a)]	108.31 ± 5.45	81.75 ± 2.14	28.58 ± 1.71	39.15	0.02	0.00	0.00	39.15
DupUM[a)]	104.22 ± 16.93	80.56 ± 4.19	20.55 ± 1.11	41.62	0.45	0.00	0.00	41.62
Leca[b)]	------	------	------	50.75	58.74	0.00	0.00	50.75

W-water; F - Formamide; BN - 1-Bromonaphthalene

As Figure 1 suggests, plastic supports have hydrophobic nature (ΔG_{SW}^{TOT}<0) while clay support and biomass exhibit hydrophilic nature (ΔG_{SW}^{TOT}>0).

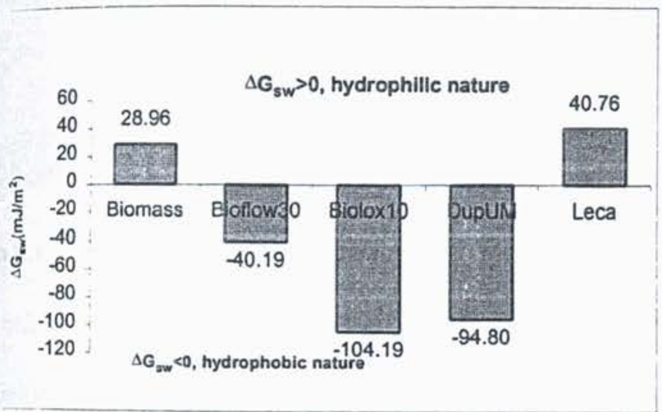

Figure 1. Free energy interaction (ΔG_{SW}^{TOT}) between the different surfaces (supports or biomass) and water, in mJ/m^2, at 20°C.

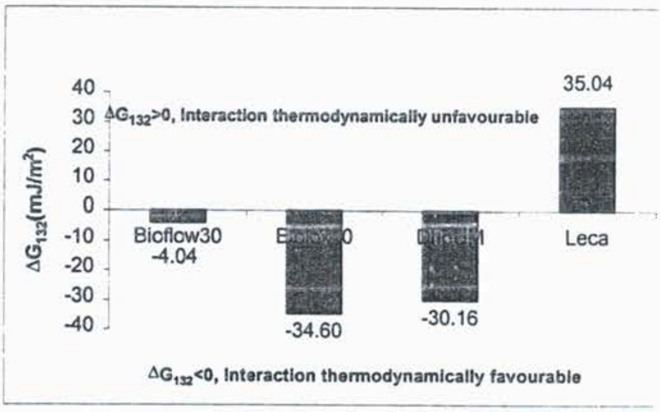

Figure 2. Total free energy of interaction (ΔG_{132}^{TOT}) between the biomass (1) and supports (2) immersed in water (3), in mJ/m^2, at 20°C.

Using the results in Table 3, the total free energy of interaction (ΔG_{132}^{TOT}) between the biomass (1) and different supports (2) immersed in water (3) was calculated, as shown in Figure 2. These results show that the biomass adhesion to plastic supports is a thermodynamically favourable process (ΔG_{132}^{TOT}<0), while the biomass adhesion to clay supports is thermodynamically unfavourable (ΔG_{132}^{TOT}>0).

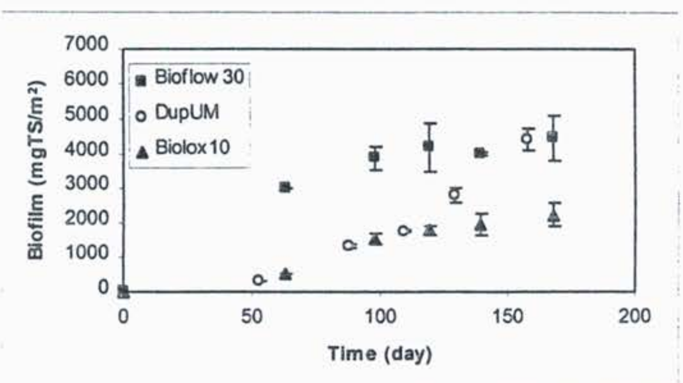

Figure 3. Biofilm accumulation on plastic supports expressed as dry weight (mgTS) per specific surface area (m^2) of each support.

Throughout the experiment, the clay support was macerated by the mixing equipment and after 10 days of operation the support was removed from the reactor. The results obtained indicated that the most favourable plastic support for the initial adhesion of biomass was the *Biolox10*. However, Figure 3 shows that *Bioflow30* recorded the higher biomass accumulation after 60 days of operation; *Biolox10* and *DupUM* presented similar values of attached biomass concentration. Therefore, the interaction between biomass, support and real effluent (not water) should be considered in future works.

CONCLUSIONS

The main conclusions drawn from this work are as follows:

a) the scheduling strategy applied for the reactor's operating cycle times ensures a good efficiency of the organic matter and nitrogen removal (94% and 80%, respectively) up to a loading of 1.2 kg $COD/m^3 \cdot d$ and 0.19 kg $N\text{-}NH_4^+/m^3 \cdot d$;
b) in future work, the use of the thermodynamic approach to predict initial bioadhesion to plastic supports should consider the interaction between biomass, support and real effluent (instead of water);
c) the used plastic supports are appropriate for the biomass adhesion and the biofilm accumulation on each support exhibited different behaviour.

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