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Microbial adherence studies for anaerobic filters

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Abstract Adherence studies of anaerobic sludge were conducted on three different solid supports for their use in Anaerobic Filters. These were, Plastic corrugated rings, PVC sheets and stones and the measurements were gravimetric, using synthetic wastewater for the growth of the microorganisms. The results are between 10% and 64% of adherence (and over 95% of COD abatement). The best results were obtained with corrugated rings, probably due to occlusion of biomass more than physicochemical adherence.

1
Introduction

The main problem encountered in the anaerobic processes is the slow growth rate of the methanogenic bacteria, which means that conventional anaerobic reactors have to be operated at large Hydraulic Retention Times (HRT), so as to prevent the washout of the *Methanogens*. Another consequence of this, is the long time needed for startup of anaerobic digesters, specially when no large amounts of inoculum are available or the inoculum is not adequately adapted to the effluent to be processed.

Different researchers concluded that the best solution to the problem was to increase the solid retention time, and make it independent of the HRT, which may be done by several ways. So, in the sixties, Young & McCarty (1969) developed the Anaerobic Filter, which because of frequent clogging and chanelling problems postponed its industrial appearance until recently. Advances in the design technology and in the previous separation of Suspended Solids (SS) by Primary Treatments, when the influent was high in SS, allowed later its adequate design and operation.

The Anaerobic Filter consists of a tower, partially loaded with a solid filling material which performs as a support for the microorganisms which adhere to it. The orientation of this filling (ordered or random) and the flow of the liquid (upflow or downflow) defines the different types of Anaerobic Filters which exist. Generally the upflow reactors are called Filters and the downflow Fixed Film reactors.

As can be seen, the solid support filling is the most important element of an anaerobic filter. The ideal characteristics of the support material (Frostell, 1978) are: high porosity, large specific surface, adequate surface properties for adherence (rugosity, surface charges, etc.), lightweight and low cost. Also attention has to be payed to the chemical characteristics of the support material, since there is proof of a close relation between these and the behavior of the reactor, due to the effect on colonization ability, ions liberated to the liquid media, etc. (Bonastre & Paris, 1989).

Many studies have been performed towards the determination of the influence of the physical characteristics of the support (type, dimensions, material, specific surface, porosity, etc.) on the reactor performance. The materials studied are of many different kinds, as: stones, ceramic and plastic rings (and other absorption tower packings), clay fragments, calcareous seaweeds, mussel shells, perforated spheres, modular plastic panels, other porous materials (as polyurethane foam) and stainless wire mesh (Henze & Harremöes, 1983; Wilkie & Colleran, 1984).

What is most difficult to perform, is the quantification of the microbial adherence. When an overall equipment behavior is studied, it is very difficult to distinguish between biodegradation due to adhered and freely moving bacteria and if the latter are dispersed or occluded.

2
Experimental procedure

The main objective of this work was to study at laboratory level microbial adherence on three different types of supports used in anaerobic filters: corrugated plastic rings (Flocor R), PVC sheets and Stones. This was performed in a system consisting of a series of agitated batch minireactors, each of 225 ml, operated at 37 °C. (Fig. 1)

Each reactor has two upper exits, one for sampling and the other for the Biogas. The methane produced was measured volumetrically by displacement in an alkaline solution (pH = 12), which absorbs the CO_2.

The nutrient solution used in all the experiments, was a synthetic mixture of components adequate for the reproduction of the microorganisms which degrade the organics of regular wastewaters and did not contain any toxic nor other inhibitors. The composition of this solution is indicated in Table 1.

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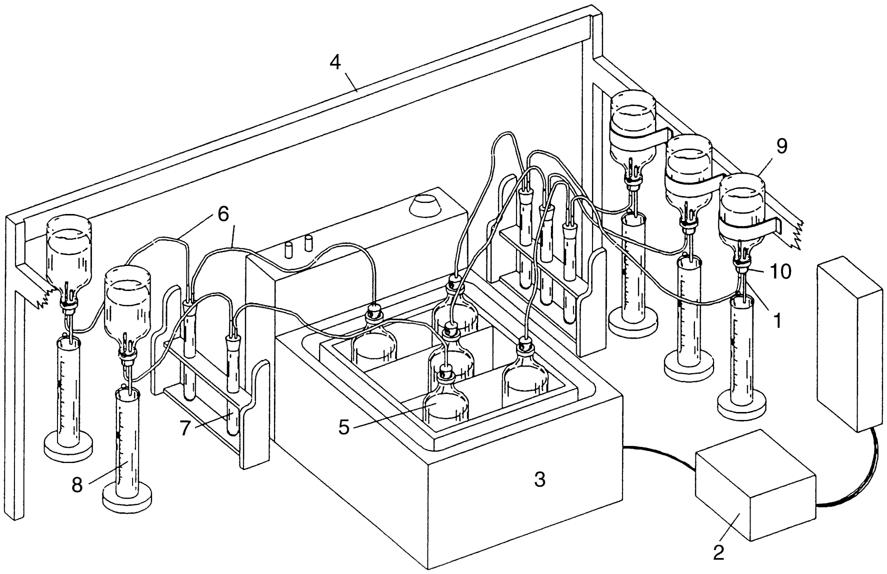

Fig. 1. Equipment outlay. 1. Glass tube, 2. Transformer, 3. Thermal bath, 4. Support frame, 5. Minireactor, 6. Plastic tubing, 7. Water trap, 8. Graduated tube, 9. Alkaline solution, 10. Stopper

The inoculum used was obtained from a wood panels factory wastewater treatment plant. Its composition is shown in Table 2.

For the startup of the reactors, 3 g SSV/l of inoculum was used, as recommended by most authors (Field *et al.*, 1988). Since the partial degradation of the sludge used as inoculum is also a source of methane and VFA, it is necessary to include a reference reactor for the determination of this contribution. Each run is made with 5 to 8 minireactors and originates one experimental point.

The fillings used were:

– **Corrugated Plastic Rings: also called Flocor R.** This type of filling is specially suited for the random distribution in the filter. The dimensions of the rings are: internal diameter = 15 mm; length = 10 mm; thickness = 2 mm; with a specific surface of 235 m^2/m^3, considered as straight cylinders and 420 m^2/m^3 including the convolutions. The filling levels were 60 pieces, occupying 70% of the volume of the reactors or 15 pieces, occupying 20% of the reactor.
– **PVC Sheets:** also called "corrugated modules". These are usually used as packing in ordered fixed bed reactors. To be able to introduce this filling into the minireactors, these sheets were cut into little pieces (30mm long, 8mm wide and 2mm thick), hence loosing its corrugated condition, which for our purpose meant no problem. The specific surface of this filling is 500 m^2/m^3 and the volume occupied approximately 10% of the reactor.
– **Stones:** this packing is the cheapest, but because of its weight, the structural costs of the reactor will be increased since it has to be more robust. The mean specific surface of this filling was 500 m^2/m^3, and the volume occupied, approximately 40%.

Table 1. Composition of the solution of nutrients*

Component	Concentration [g/l]
Sucrose	4.0
Urea	0.125
K_2HPO_4	0.037
$MgSO_4$	0.080
$NaHCO_3$	4.0
NaCl	0.3
Yeast Extract	0.2

*The nutrient solution has a COD between 4500 and 5000 mg/l.

Table 2. Mean composition of the inoculum

Component	Concentration [g/l]
Ammonia	312
pH	7.8
COD	15000
TSS	27500
VSS	10200

Procedure

i) The configuration of the system is shown in Fig. 1. The minireactors are put into a "shaker" at 37 °C.
ii) The dry filling to be loaded is weighted and introduced into the reactor.
iii) Equal total amounts of inoculum, nutrients and water are added to each reactor, for a specific run. In the "reference" reactor, the same amount of inoculum is added and the volume is completed with water, but no nutrients are added.
iv) N_2 or CO_2 is insuflated through each reactor, to assure anaerobic conditions.
v) The reactors are agitated to homogeneity and the sample for time = 0 is taken.
vi) The minireactors are connected to the Biogas measurement system.
vii) After different times of operation, sequentially, the filling of the minireactors is extracted, dried and weighted.

Control of the runs

The following parameters were measured: COD, TSS, VSS, pH and methane produced, which allows to assure the adequate functioning of the reactors.

Calculations

The adherence is calculated gravimetrically from the initial and final mass of the dry filling. Then the difference gives the total amount of microorganisms adhered, taking into account the original biomass used as inoculum.

The initial mass of microorganisms, or, the mass available for adherence, is calculated from the following formula:

$$IMM = Vr \cdot TSS \ , \qquad (1)$$

where, IMM = initial mass of microorganisms in [mg], Vr = active volume of the reactor in [l] and TSS = initial total suspended solids in [mg/l].

The adhered mass to the packing is calculated as follows:

$$AMP = FMP - IMP \ , \qquad (2)$$

where, AMP = dry mass adhered to the filling in [mg], FMP = final mass of the support (dry base) in [mg] and IMP = initial mass of the support (dry) in [mg].

With Eqs. (1) and (2) the percentage of microbial adherence (% A), is calculated as follows:

$$\%A = \frac{AMP}{IMM} \cdot 100 \ . \qquad (3)$$

Note: The adherence is related to the initial mass of microorganisms and not to the final or true mass of microorganisms present at the end of a run. But since these studies are conducted for the comparison between different fillings, it is adequate as a relative condition of adherence for startup and operation purposes.

3 Results and discussion

3.1 Plastic corrugated rings

In Fig. 2 are shown the results obtained for microbial adherence and COD reduction. In this case there were two series of runs: a) with 60 rings, and b) with 15 rings in the packing.

In case a), the maximum adherence found was 64% after 13 days. This value remains constant for all further days. It has to be noted here that this behavior is consistent with other studies made in this direction and is an indication that the contribution of occluded biomass might be important (Guerrero, 1992; Soto, 1990).

In case b), the maximum adherence found was 23% after 13 days, this low value even decreased in further days. This is probably due to the freedom of displacement of the rings within the unfilled reactors (subjected to movement in the shaker), which caused collisions between them and loosening of poorly adhered biomass and most of that occluded in the convolutions of the rings.

The COD reduction for both cases a) and b), was similar, reaching a final value of 96% but in case a) the velocity of reduction was slower. This is due to the fact that in case b) a larger portion of the biomass was freely moving and hence the mass transfer between the wastewater and the microorganisms was facilitated. The same results are obtained when anaerobic filters are compared with UASB reactors.

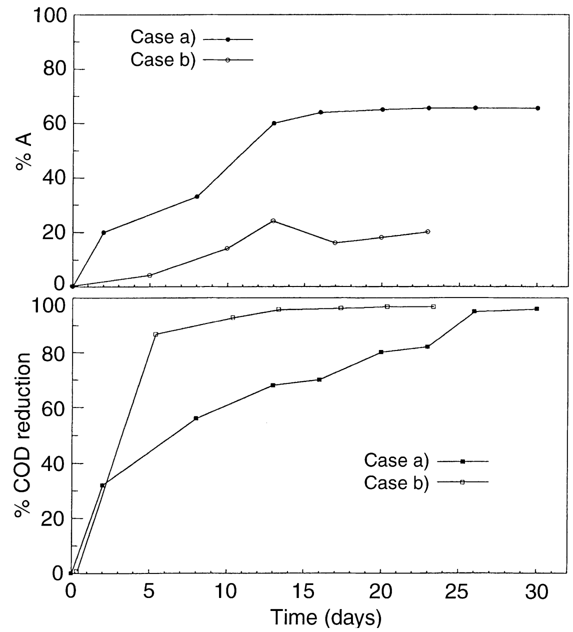

Fig. 2. Adherence and COD reduction with corrugated rings

3.2 PVC sheets

In Fig. 3 are the results for microbial adherence and COD reduction. In this case only a 10% of adherence is achieved after 23 days of operation, indicating a poor affinity between the microorganisms and the surface of the support material. However in this case also the reason may be the same as for the rings, the relative movement between the solid pieces of filling within the reactor during the runs. The COD reduction is 97%, which is high, and proof of the contribution to it by unadhered biomass.

3.3 Stones

Figure 4 shows the results obtained with stone fillings of the reactor for microbial adherence and COD reduction. It can be seen that the maximum adherence achieved is 17.5% after 35 days of operation, which also shows low affinity between the microorganism culture and the solid surface of the stones. Again the COD reduction is over 95%, showing the adequate activity of both, adhered and freely moving biomass.

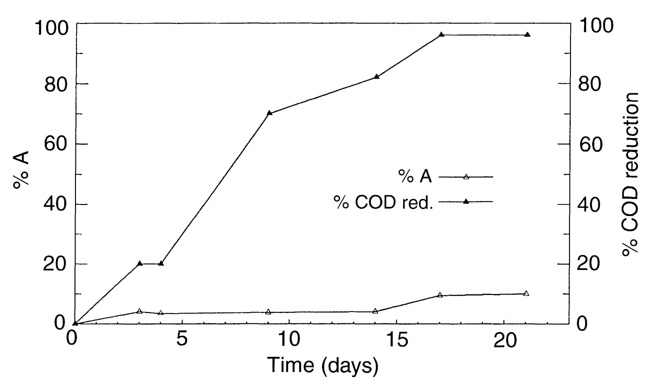

Fig. 3. Adherence and COD reduction with PVC sheets

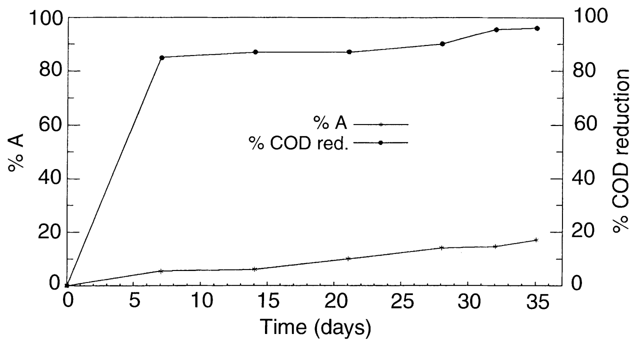

Fig. 4. Adherence and COD reduction with stones

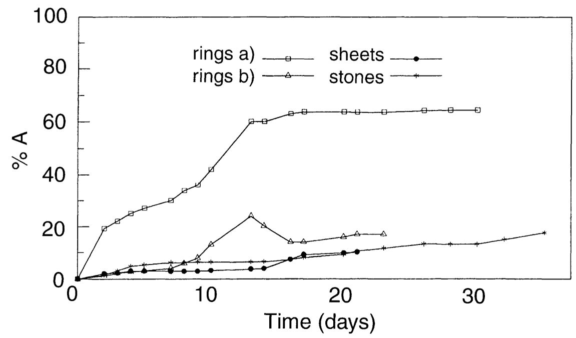

Fig. 5. Microbial adherence on different support materials

4
Comparison between the different packings studied

The specific surface of the packings is very similar (500 m^2/m^3), except for corrugated rings, which was 420 m^2/m^3, these giving even better results, which is proof of the occlusion effect on the adherence and the degradation. The latter implies that even better results should be expected for full size PVC sheets, which are of ondulated (corrugated) shape, since these ondulations provide space for occlusion and were lost by being cut in pieces for our experiments.

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