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APPLICATION OF THE BIOBED® UPFLOW FLUIDIZED BED PROCESS FOR ANAEROBIC WASTE WATER TREATMENT

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ABSTRACT

Over the past ten years Gist-brocades has been engaged in anaerobic waste water treatment. An in-depth research program concluded in the construction and operation of three full-scale plants for the treatment of yeast processing and pharmaceutical waste waters. Using the operational experience of the fluidized bed biomass-on-carrier systems and incorporating the strong assets of the Upflow Anaerobic Sludge Blanket (UASB) system features a new process was developed, the so-called Upflow Fluidized Bed (UFB) BIOBED® process, which operation appeared to be very successful over a > 3 year period at full scale. The UFB BIOBED® system combines both characteristics of the UASB and FB processes. Biomass is present in a granular form but conditions with respect to upflow velocities for water and gas approach those of the original Fluidized Bed - biomass on carrier - (FB) system.

KEYWORDS

Anaerobic Waste Water Treatment; UASB; Fluidized Bed; Upflow Fluidized Bed; Yeast production

INTRODUCTION

Anaerobic treatment of industrial waste waters is by now a well established technology which has proven to be successful in a wide range of applications (Stronach et al., 1986) (Borghans et al., 1986).

The key to this successful operation is the way in which the anaerobic biomass is retained in the reactor system, thus making the biomass retention time independent from the liquid retention time.

Systems development has taken the approach of reducing the hydraulic retention time as far as possible, thereby reducing the overall size of the treatment system and improving the economic feasibility of the technology.

The most widely applied methods of biomass retention in high loaded anaerobic systems are immobilization of the biomass on a fixed or mobile carrier such as upflow/downflow fixed bed systems (Young et al. 1969), fluidized or mobile bed systems (Heijnen et al., 1986) (Cooper et al., 1981) and rotating disks (Tait et al., 1980) or the spontaneous granulation systems like in UASB (Lettinga et al., 1979), EGSB (De Man et al., 1988) or hybrid systems (Reynolds et al., 1988)

Gist-brocades has applied anaerobic treatment to five of their production plants. Four of them are treating waste water from yeast production and one is for treatment of a combination of yeast and pharmaceutical production waste water. See Table 1.

TABLE 1: Use of Anaerobic Waste Water Treatment at Gist-brocades NV Production Plants

Plant	Wastewater	Treatment since	Technology
Eagle yeast, Old Bridge USA	Yeast	1983	UASB (BIOTHANE®)
Gist brocades, Delft The Netherlands	Yeast & Pharmaceuticals	1984	FB
Gist brocades, Prouvy France	Yeast	1984	(U)FB (BIOBED®)
Gist brocades, Vinal Italy	Yeast	1986	UASB (BIOTHANE®)
Uniferm, Monheim FRG	Yeast	1987	UFB (BIOBED®)

The UASB technology applied is known under the trademark BIOTHANE® and has been described in previous articles (Borghans et al., 1986).

This article will overview the state of the art of fluidized bed - biomass on carrier - technology as applied by Gist-brocades for over 5 years, and will subsequently outline which approach has been taken to overcome the draw-backs of this technology. As a result, a new type of anaerobic treatment process was developped that combines the strong assets of both UASB and FB technologies.

FLUIDIZED BED TREATMENT AT GIST BROCADES, DELFT

Since 1984 a full scale FB installation has been in use for the treatment of yeast and pharmaceutical production waste water. The original outline of the plant and its performance during and close after start-up were presented earlier by Enger et al., 1986. Also the character of the effluent has been described earlier by Heijnen, 1984.

The design of the plant and the present waste water can be characterized by Table 2.

TABLE 2: Plant Characteristics Gist-brocades, Delft, 1990

Flow	6000-6500	m^3/d
Chemical Oxygen Demand (COD)	3800-5000	mg/l
COD Load	22-29	tons/d
Total volume per reactor	400	m^3 (4 No)
Reactor height	21	m
Reactor diameter	4.7	m

Figure 1 gives a flow scheme of the plant.

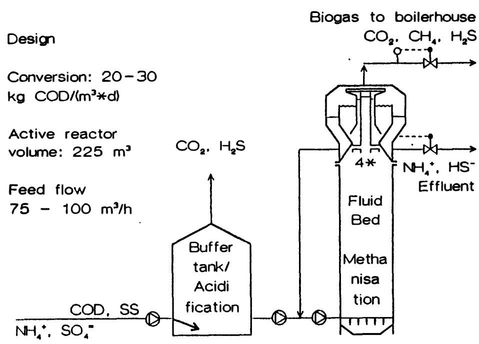

Fig. 1. Flow scheme fluidized bed waste water treatment plant Gist-brocades, Delft

Table 3 summarizes the performance of the plant for the year 1990

TABLE 3: Performance Data (1990) Fluidized Bed Plant Delft

COD loading rate (V-tot*)	16 - 21 kg $COD/m^3.d$
Gas production	5000 - 7000 Nm^3/d
Removal efficiency COD	50 - 60 %
Volatile fatty acids effluent	20 - 450 mg/l
Liquid upflow velocity	± 15 m/h
Gas upflow velocity	± 4 m/h

* Total volume excl. gasbuffer in the head of the reactor

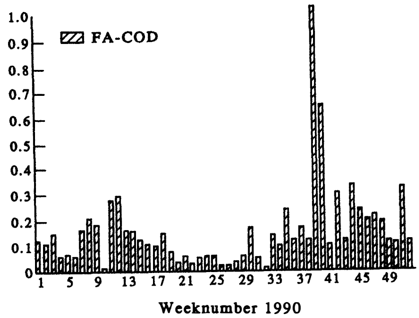

Fig. 2. Volatile fatty acids reactor effluent

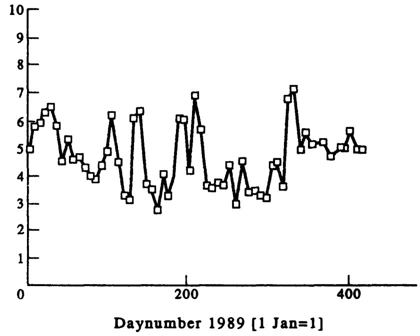

Fig. 3. Reactor 2: total organic dry matter

Figure 2 shows the VFA concentration in the effluent of the fluidized bed reactor. From week 20 - 32 it becomes obvious that a level of < 50 mg/l is possible. However, this low level is not achieved most of the time. It can be concluded that the reactor is continuously in a stressed/overloaded condition. This can further be explained if one considers the amount of biomass which is retained in the fluidized bed reactors.

Figure 3 and 4 show the total quantity of organic dry matter (tons) in 2 of the 4 reactors. It is shown that there are great fluctuations on a relatively short time scale. The maximum amount of biomass retained is approximately 6 tons of Volatile Suspended Solids (VSS), the average value being closer to 5 tons VSS. With loadings of up to 20 tons COD per day (± 5 tons COD per reactor) sludge loadings of close to 1 kg COD/kg VSS.d can be calculated. Considering the recalcitrant nature of the pharmaceutical part of the waste water this would be a too high value for stable continuous operation, thus leaving VFA in the anaerobic effluent. With this analysis it should be noted that the sampling procedure for biomass in FB reactors is extremely difficult and the above review is indicative only.

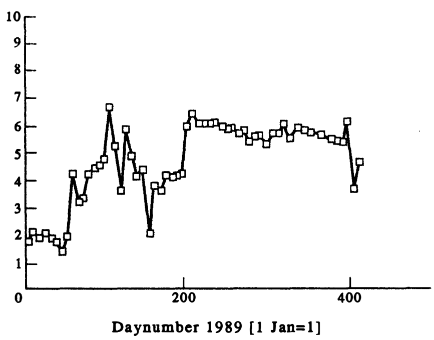

Fig. 4. Reactor 2: Total organic dry matter (tons)

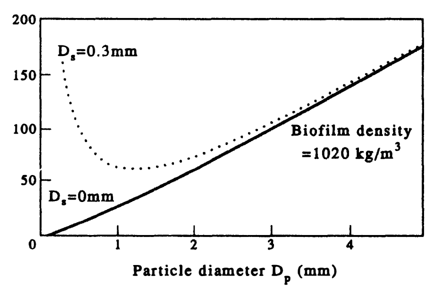

Fig. 5. Max. fluid velocity at 35 °C (m/h)

During the operation of the plant there was never any excess sludge withdrawn from the system. From sludge samples taken over the height of the reactor it has now become apparent that at the bottom part of the reactors only bare carrier material is present. This phenomenon has also been found in other FB systems. This can be explained by the extreme shear conditions which are present at the outlet nozzles of the influent distribution pipework. Such extreme conditions are neccesary to keep the basalt carrier in a fluidized state. So all the active biomass is present in the middle and top part of the reactor.

In the top part of the reactor there is a tendency for biomass particles to grow bigger, due to the locally mild shear conditions. The result of this is that the overall density of the particles decreases and on the basis of theoretical calculations it can be shown that particles of > 2 mm (with a carrier mean diameter of 0.3 mm) will have approximately the same settling velocity as the granules of this diameter found in UASB systems (Figure 5). Due to the high liquid velocity of ± 15 m/h in the FB reactor (necessary to fluidize the carrier material), these particles tend to wash out of the system.

With the above considerations and the results obtained from the full-scale installation, it was concluded that a sensitive equilibrium exists with respect to the biomass retention; none or limited growth on the carrier at the bottom part and wash out of bigger sludge particles at the top part of the reactor. The net result is a maximum potential of 6 tons of VSS in a 400 m^3 reactor, which is too low for a system running at a COD volumetric loading rate of 16 - 21 $kg/m^3.d$.

Process Stability

From Figure 2 it can also be seen that the recovery of the system after an upset condition (eg week 10, 38) takes a relatively long time. This can be explained by the fact that the process of biofilm formation is slow and after a situation whereby biomass is lost from the system usually it takes some two months to build up the maximum possible concentrations. Due to the fact that a limited amount of biomass can be retained in the reactor, the system has no inherent buffering capacity towards shockloads in toxicants or COD. Overall the stability of the process is therefore limited.

UFB BIOBED® Pilot Plant

Based on the above it was decided to run a pilot-plant UFB Biobed® parallel to the full-scale plant to assess the feasibility of this mode of operation for the Delft waste water.

In Figure 6 the ratio of gas to water is shown for the full scale and pilot plant for a three month period. It was found that with this pilot plant a constant level of VFA in the effluent was achieved of less then 50 mg/l at loading rates continuously above those for the full-scale plant. The graph also clearly indicates that the pilot unit is able to produce more gas from the same amount of COD. Although the influent to both reactor systems was not completely the same, the effect was very significant.

Based on these observations it was concluded that reconstruction of the FB biomass-on-carrier reactors into an Upflow Fluidized Bed system would significantly increase the performance and system reliability. This decision for modification (for two of the four reactors) was also strongly supported by the results obtained with the full-scale UFB BIOBED® performance at UNIFERM, Monheim.

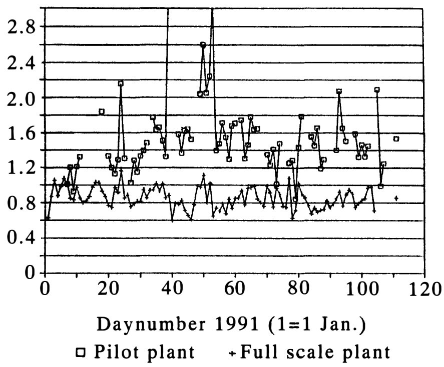

Fig. 6. Ratio gas - waterflow (-)

BIOBED® UFB TREATMENT UNIFERM, MONHEIM

The waste water from Uniferm Monheim arises from the production of bakery yeast. It is a combination of evaporator condensate (the evaporator concentrates the strong molasses waste) and a reverse osmosis permeate (where low-strength waste waters are concentrated) and contains mainly fatty acids and alcohol. See Table 4.

TABLE 4: Waste Water Characteristics Uniferm Monheim, 1989

Total COD	2500 - 3500 mg/l
Disolved COD	2500 - 3500 mg/l
Volatile fatty acids	930 mg/l
pH	4

Figure 7 shows a schematic of the UFB BIOBED® reactor. In comparison with the Delft reactors modifications were made to the influent distribution system to ensure mild shear conditions at the bottom part of the reactor, and improvements were made to the settler in the top of the reactor to cope with the extreme hydraulic loadings and retain the granular biomass without the carrier. Figure 8 gives the total flow scheme of the plant.

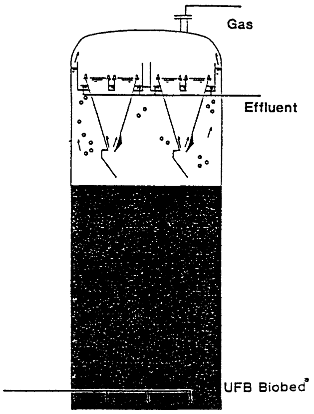

Fig. 7. UFB BIOBED® reactor

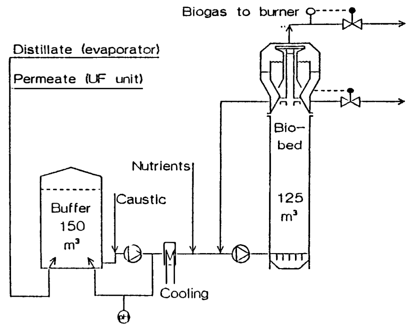

Fig. 8. Flow sheme Uniferm, Monheim

In Table 5 the operational data for the year 1989 are summarized. More specifically results on wastewater flow (Fig. 9), COD concentrations (Fig. 10), COD removal efficiency (Fig. 11) and volumetric loading rate (Fig. 12) are presented.

TABLE 5: Summary Operational Data UFB BIOBED® Plant Uniferm, Monheim, FRG

	Average	Range	unit
Flow	587	300-900	m^3/d
COD concentration	2580	1900-4000	mg/l
COD load	1514	1000-2400	kg/d
Loading rate	16.8	8-30	$kg/m^3.d$
Removal efficiency	96.5	95-98	%
Gas production	663	300-1100	Nm^3/d
VFA effluent	<25	<25	mg/l
Liquid upflow velocity	4	2-6.5	m/h
Gas upflow velocity	13	13	m/h

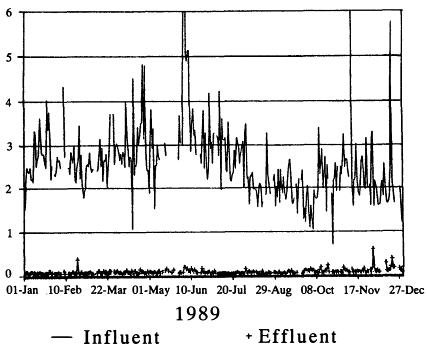

Fig. 9. Waste water flow

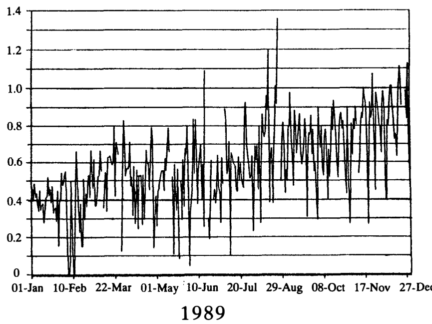

Fig. 10. COD concentrations

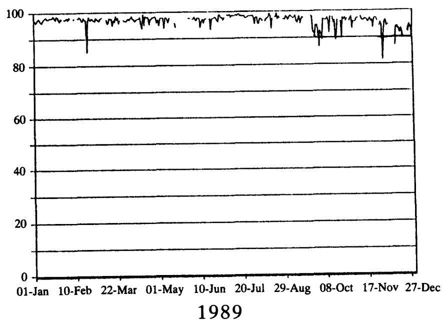

Fig. 11. COD removal efficiency (%)

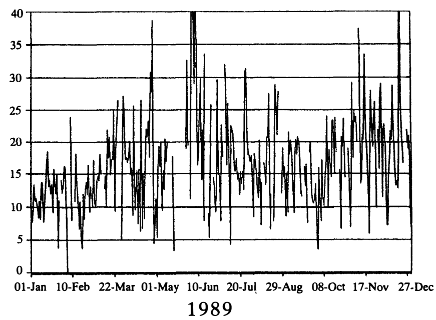

Fig. 12. Volumetric loading (kg COD/m^3.d)

From the presented results it becomes obvious that the performance has been excellent. Despite the wide influent fluctuations and at some times excessive loadings, the system showed a great stability and constant effluent quality. With the operation of this plant it has now been proven on full scale that granular biomass can be retained in this modified fluidized bed system at gas and liquid upflow velocities of 6.5 and 13 m/h respectively. The function of the improved settler hereby is believed to be essential. Actually, growth of sludge has been observed and from time to time excess sludge had to be withdrawn from the reactor.

CONCLUSIONS

The performance of the FB biomass-on-carrier system as applied by Gist-brocades for over 5 years proved to be unsatisfactory. The main drawback can be found in the inability of the system to retain sufficient biomass for reliable and stable operation. A new type of fluidized bed system was introduced which combines the strong features of both UASB (granular biomass, without carrier) and FB biomass-on-carrier systems, the so-called UFB BIOBED® system.

The most striking features can be summarized as:

- High loading capabilities; 15-30 kg $COD/m^3.d$
- Compact reactor footprint
- Use of granular biomass; quick (re) start-up
- Excellent biomass retention with improved settler design
- No accumulation of inert solids due to high liquid throughputs (high liquid upflow velocities)
- High recirculation flows can be used for internal dilution of toxic, biodegradable compounds
- Physical shape of the reactor allows construction in non-corrosive materials (GRP,plastics)

Summarizing it can be concluded that with the UFB BIOBED® technology excellent results were obtained on lab (not presented), pilot-plant and full scale. The expectations regarding the applicability of this technology for different waste waters, both industrial and domestic, are promising.

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