EFFECT OF THE FLOCCULANT PERIODICAL ADDITION ON THE PERFORMANCE OF A SEQUENTIAL BATCH REACTOR TREATING DAIRY WASTEWATER

A. Ferrari[1*], A. Benítez[1], P. Lema[1], C. Irigoyen[1], S. Gutiérrez[1]. D. Travers[2] C.Etchebehere[2],
[1]Facultad de Ingeniería - Universidad de la República Oriental del Uruguay.
[2]Facultad de Química - Universidad de la República Oriental del Uruguay.

Abstract. The operation of a laboratory scale sequential batch reactor fed with dairy wastewater was investigated. During the operation of this reactor, the effect of a minimum periodical pulse of cationic flocculant addition over the removal capacity was evaluated. The reactor performance (COD and Nitrogen removal, solids concentration and settling capacity) was followed during more than 4 weeks before and 2 months after periodical polymer addition. A plexiglass lab-scale reactor of 15 L working volume was operated with semi-synthetic dairy wastewater (~ 3 gCOD/L, C/N ratio ~ 30, 4L/d). This effluent was obtained by whole milk dilution and by sodium nitrate addition in order to simulate nitric acid washings and neutralization (with sodium hydroxide solution) operations, employed at many dairy plants cleaning routines. The reactor operates at 2 cycles by day as follows: an anoxic phase (feeding included), an aeration stage, a settling phase and a drainage final stage. Sludge age was maintained at 20 days. Respirometric batch tests were periodically conducted in order to evaluate the maximum heterotrophic degradation rate. Once polymer addition starts, settling velocity was effectively enhanced and SVI was reduced. Average COD and Nitrogen removal efficiency (94-99% and 90-99% respectively), were maintained. The evaluation of respirometric tests revealed a considerable variability of sludge heterotrophic activity before flocculant addition (mean value of ~ 510 mgO_2/gVSS/d). However, after polymer treatment this activity was stabilized but at a lower mean value (~ 250 mgO_2/gVSS/d). This periodical flocculant addition, besides of improving sludge settling capacity, did not affect the reactor performance. Nevertheless, the activity tests results suggests that the performance of flocculated sludge could affect the reactor removal efficiency in more demanding operating conditions (lower HRT for example).

Keywords: Sequential Batch Reactor, Flocculation, Bulking.

1. Introduction

Many dairy factories employ continuous biological treatment systems in order to perform wastewater required depuration. In some cases, anaerobic/aerobic/anoxic series processes have been applied and studied (Castro et al., 2000) (Garrido et al., 2001). In other cases, single aerobic stages can be used to perform the complete wastewater depuration, spending sometimes high energy costs due to the required continuous aeration.

The Sequential Batch Reactor (SBR) technology appears as a feasible and simple alternative which requires only one tank for reaction and settling, allowing continuous control and regulation of its critical operative parameters (stages duration, air supply, etc.), which is advantageous to overcome the problem of establishing the optimal operation condition.

The sludge bulking is a common critical trouble for activated sludge and SBR systems. Polymer addition in a secondary clarifier tank is a common practice in activated sludge full scale facilities (Novak and Havriikova, 2004). For SBR systems, flocculant addition has been considered by polymer suppliers.

The aim of the present work is to study the polymer addition as a solution for overcoming bulking problems in a SBR reactor treating dairy wastewater. The effect of flocculant addition was investigated, at a lab-scale reactor, in terms of its influence over reactor performance and heterotrophic activity, in addition to sludge settling conditions.

[*] To whom all correspondence should be addressed.
Address: Facultad de Ingeniería, UDELAR – Instituto de Ingeniería Química, Julio Herrera y Reissig 565 Montevideo – Uruguay
E-mail: aferrari@fing.edu.uy

2. Materials and Methods

2.1. Influent

The lab-scale 15 L reactor was fed with a semi-synthetic dairy wastewater, prepared diluting whole milk and adding sodium nitrate solution, to simulate the wastewater generated in certain dairy plants.

Sodium nitrate is added to simulate industrial wastewater, as dairy plants employs nitric acid and sodium hydroxide during its washing routines.

The influent is prepared daily and maintained at 4ºC in a 15 L tank. A previous experimental study was carried out to determine the average composition of an industrial dairy plant wastewater. Influent average characteristics were the following: 3000 mgCOD/L, 60 mgNTK/L, pH = 6.2 and 80 mgN-NO_3^-/L.

2.2. Operating Conditions

The reactor employed is cylindrical with a semi-spherical bottom. It has 20 L of maximum liquid capacity, and its geometrical features are the next:

- Height: 60 cm.
- Diameter: 23 cm.

The reactor operation is fully automatic. It consists on automatic load and drainage commanded with a electrode control level system, a mixer automatically activated, an aerator system composed by a compressor and an air flow meter, and a controlled purge pumping at a fixed flow rate. Additionally, a recycle with a controlled pump was installed to connect on line sensors: temperature, dissolved oxygen and pH measurements.

The data acquisition, historical management, alarms, reports and operator interface is carried out by an SCADA system. It was implemented as an Intellution FIX ® application.

The SBR operation consists in 2 cycles by day (12 hours each). The operation times employed for cycles are shown in figure 1.

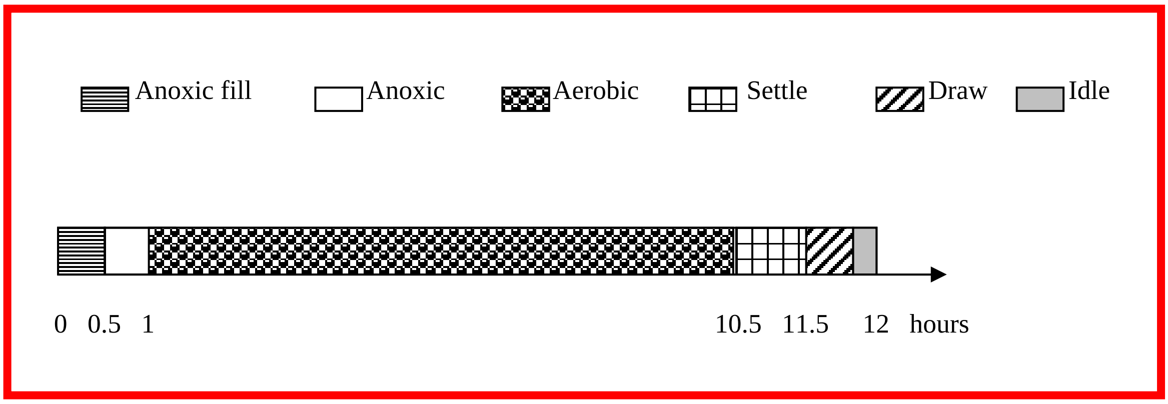

Fig. 1. Cycle setting time.

More details about reactor operating conditions are described in Gutiérrez et al., 2005.

Polymer addition started about two months after reactor operation began. Flocculant solution pulse was added to the reactor every 10 days, resulting in a initial concentration of 5 mg/L in reactor mixed liquor. Minimum dose was employed in order to minimize operation costs. The flocculant used was PRAESTOL 644 from Stockhausen GmbH & Co.

2.3. Experimental Data

The reactor was operated for about ten months, and during this period the following parameters were measured: Volatile and Total Suspended Solids (VSS and TSS), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Kjeldhal Nitrogen (TKN), Ammonia Nitrogen (N-NH_4^+), Sludge Volumetric Index (SVI) and Sludge Heterotrophic Activity. In table 1, the procedure employed is resumed.

Table 1. Parameters and techniques summary

Parameter	Principle	Reference
VSS, TSS	Gravimetric method	1
BOD_5	Respirometric method	1
COD	Dichromate oxidation/espectrophotometric method	1
TKN	Kjeldhal digester/titration method	1
$N\text{-}NH_4^+$	Titration method	1
SVI	Imhoff cone	1
Sludge heterotrophic activity	Respirometric test	Annex 1

1 – APHA (1995).

The total influent, total effluent and the mixed liquor were analyzed.

Settling velocity (Vs) was measured to evaluate sludge settling properties: Once aeration and mixing are off, initial time and total liquid volume (usually between 13.0 and 15.0 L) are registered. The time needed to reduce the sludge volume to 5.0 liters is recorded.

Microbiological methods In order to study the microbiology of the reactor, a potential heterotrophic activity test was conducted . The rate of oxygen consumption for the heterotrophic organisms was measured by respirometric activity tests. The oxygen uptake rate (OUR) for oxygen consuming was determined as was described in Cabezas et al., 2004. Substrate concentration used in the tests was 200 ppm COD as acetate. The potential activities were expressed as mgO2/gSSV.d.

3. Results and Discussion

Average removal efficiencies were highly satisfactory (94-99% for COD and 90-99% for total nitrogen) and output average liquid quality parameters were: COD less than 90 mg/L, BOD5 less than 15 mg/L and total nitrogen less than 5 mgN/L. Although the input nitrate in the system is removed by denitrification, the sludge growth was the main responsible for the nitrogen removal in the reactor. Autotrophic processes are negligible. Reactor performance was described in Gutiérrez et al, 2005.

3.1. Settling characteristics

Volatile Solid content in the reactor varied between 2 and 4 g/L most of the time.

The setting velocity evolution, before and after polymer addition is showed in Figure 3. Average settling velocity was 0.0056 and 0.0093 cm/s before and after addition respectively. It can be seen that during the first period the settling velocity showed higher variability than the second period. Setting velocity was improved in 40%.

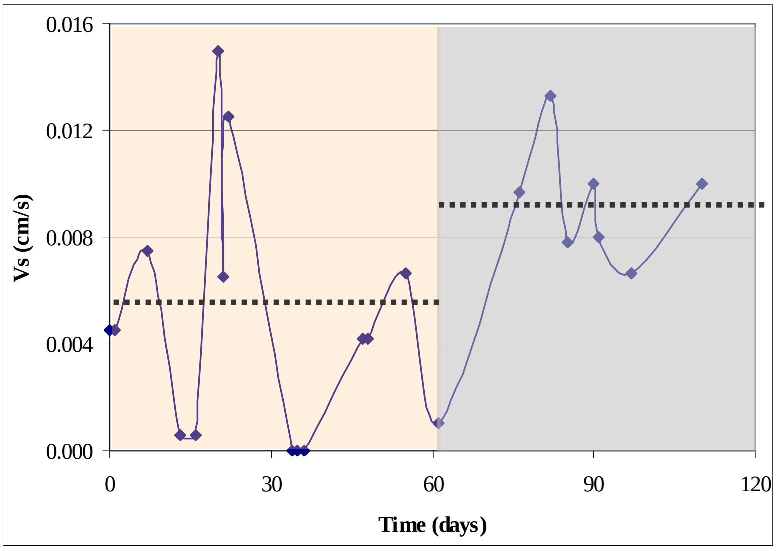

Fig. 3.- Settling velocity evolution before and after polymer addition. *before:* clear zone, *after:* grey zone. Straight line corresponds to mean value of each period.

The solid content of the effluent which leaves the reactor is another parameter useful to evaluate settling properties. The sludge blanket is allowed to settle during the settling phase of the reactor operation, and the supernatant is withdrawn after that. The suspended solid appearance in the effluent could be due to two reasons: 1.- part of sludge blanket is withdrawn with the supernatant if it doesn't reach the required level, and 2.- poor flocculation capacity of the sludge, giving dispersed biomass in the supernatant. In Figure 4.- the evolution of total and volatile suspended solid content are presented. It is possible to see that the effect of polymer addition decreases solid content in the effluent (average values for volatile suspended solids are. 297 and 138 mg/L before and after flocculant addition)

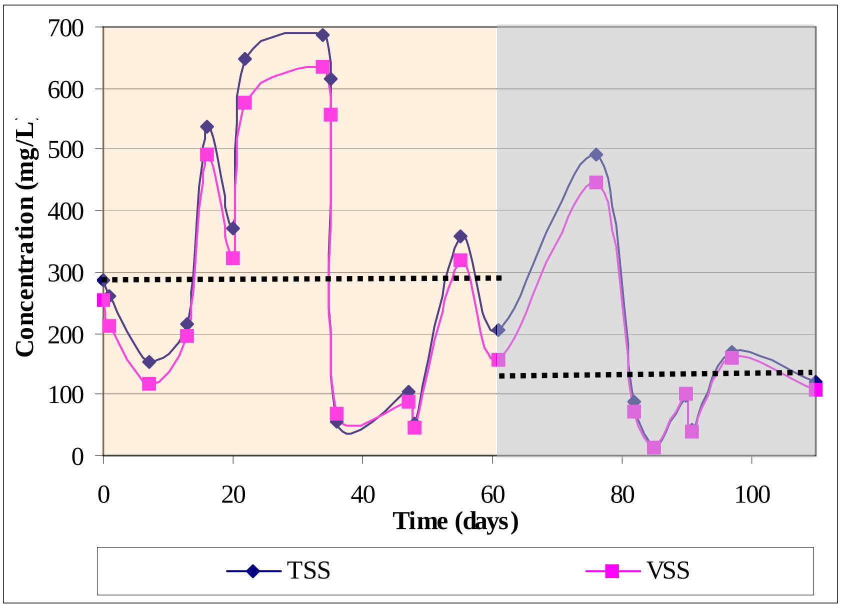

Fig. 4 Total and Volatile suspended solids in reactor effluent evolution *before:* clear zone, *after:* grey zone. Straight line corresponds to mean value of each period

In Figure 5 the SVI evolution is presented. This parameter allows to evaluate the degradation of the settling properties, describing the compacting degree of the sludge. The SVI values were increasing (worse condition) up to day 61, and decreasing after flocculant addition, reaching values around 200 mL/g.

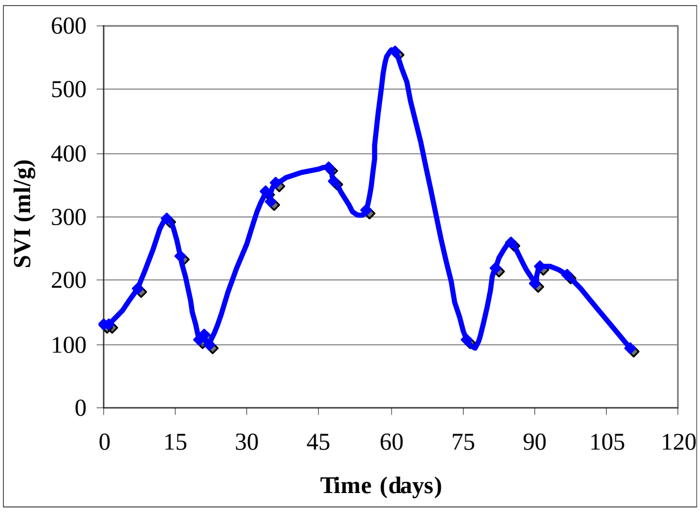

Fig. 5. Sludge volumetric index.

3.2. Heterotrophic Activity

Heterotrophic potential activity is presented in Figure 6. It can be seen that this parameter presents a high variability during the first two months, with a corresponding mean value of 510 $mgO_2/gVSS/d$. After day 61, when programmed flocculant addition starts, activity was stabilized but in a mean value of 250 $mgO_2/gVSS/d$. The addition of flocculant seems to select a more stable microbial population. However it presented a lower specific degradation rate.

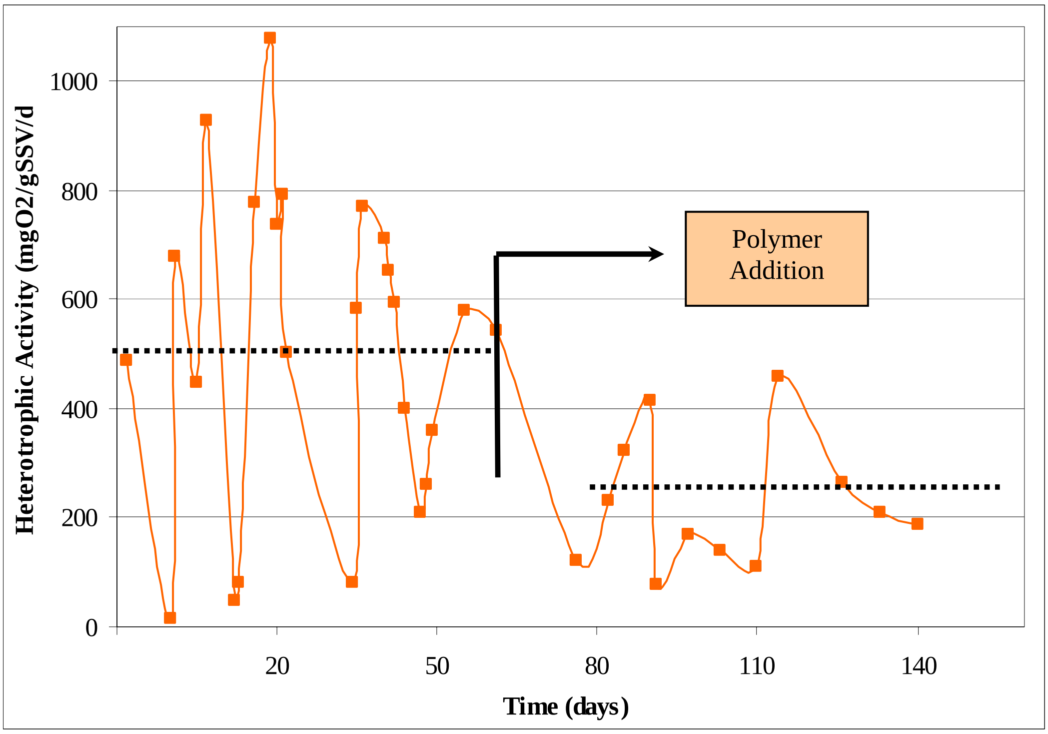

Fig. 6. Heterotrophic activity evolution. Straight line correspond to mean value of each period

3.3. Reactor Removal Efficiency

The average soluble COD and TKN removal efficiency before polymer addition began ranged within 95-99% and 90-99% respectively. Beyond this action, the results were maintained: 96-98% for COD and 91-98% for N removal. As described in Gutiérrez et al, 2005, the aeration period is long enough to allow the total removal of organic matter even the drop in activity value.

4. Conclusions

Settling velocity was effectively improved (40%) while SVI and volatile suspended solids in the effluent were reduced. (around 50% for suspended solid concentration), reaching the operation objective in actual lab-scale conditions (sludge blanket below the drainage point at the end of settling phase). However, the SVI value is still high compared with recommended parameters (150 mL/g Grady, 1998), and a higher flocculant concentration could be necessary to improve the settling conditions for safer real scale operation.

After polymer treatment, the microbial activity was more stable but at a lower mean value (around 50% less). The addition of flocculant seems to select a more stable microbial population., however it presented a lower specific degradation rate. Although reactor operation with the flocculated sludge could result in a more predictable condition, its maximum wastewater treatment capacity will be lower. Further research should be conducted to test the effect of different flocculant agents over the microbial selection, in order to improve its heterotrophic activity.

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