SEQUENTIAL BIOLOGIC TREATMENT OF FOOD PROCESS EFFLUENT
TRAITEMENT BIOLOGIQUE SEQUENTIEL D'EFFLUENTS AGRO ALIMENTAIRES

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ABSTRACT: After experimenting the conventional activated sludge process we devote this phase to the treatment of dairy effluents, strongly loaded with organic matter, by a sequencing batch biological reactor (SBR).This study aims to evaluate treatment performance by COD and TSS reduction under the influence of organic load (COD) and aeration time variations. The results show that whatever the COD of the effluent to be treated varies from 220 to 7000 mgO_2/l, the treated effluent COD is reduced when aeration time increases. For applied COD low levels (220 - 2640 mgO_2/l), 20 hours aeration time appears to be an optimum value ensuring an effluent composition very much in line with the discharge standards (< 120 mg O_2/l). This result shows that the choice of sequential bioreactor is more advantageous than the conventional activated sludge process, used], which required 24 hours of ventilation with 100 % recycling to eliminate only 1250 mg COD/l. For organic loads to the largest entry (3120 - 7000 mg/l), the required aeration time is higher. Thus, it takes 48 hours to reduce 7000 mg COD/l to a value hardly consistent with the discharge standard for the nature of the sludge produced (filaments) and the settling time limit process performance. It also appears that the COD removal efficiency depends on the volumetric loading values (Cv) and applied mass loading (Cm) and biomass age. For Cv values ranging from 0,075 to 2.52 kg DBO_5/m^3/d and Cm values between 0,05 and 2 kg DBO_5/kg MVS/d, performance is inversely proportional to the applied load and varies roughly from 80 to 99% for Cv and from 90 to 99% for Cm. The sequential bioreactor appears more advantageous than the conventional activated sludge process that requires 4.5 days of aeration to remove 6210 mg COD/l without recycling, with volumetric loading from 0.29 to 0.92 kg BOD_5/m^3/d and mass loads from 0.17 to 0.42 kg BOD_5 /kg MVS/d.

Keywords: *Food processing effluents, dairy effluents, biological treatment, sequencing batch reactor.*

RESUME : Après avoir expérimenté le procédé par boues activées classique, nous consacrons cette étude au traitement biologique séquentiel d'effluents de laiterie fortement chargés en matières organiques. Cette étude consiste à évaluer les performances du procédé sur la réduction de la matière organique (exprimée DCO) sous l'influence de la charge organique appliquée et du temps d'aération. Lorsque la DCO appliquée varie entre 220 et 6200 mgO_2/l, les résultats obtenus montrent que la DCO de l'effluent traité diminue avec l'augmentation du temps d'aération. Pour des DCO d'entrée dans le réacteur allant de 220 à 2640 mg O_2/l, un temps d'aération de 20 heures permet de produire un effluent de composition conforme aux normes de rejet (DCO< 120 mg O_2/l).Ce résultat montre que le choix du bioréacteur discontinu est plus avantageux que le procédé par boues actives testé par, qui a nécessité 24 heures d'aération avec un taux de recyclage de 100 % pour n'éliminer que 1250 mgO_2/l exprimée en DCO. Pour des charges organiques plus élevées à l'entrée du bioréacteur comprises entre 3120 et 7000 mgO_2 /l, le temps d'aération requis est encore plus important. Ainsi, il faut 48 heures d'aération pour réduire une DCO d'entrée de 7000 mg O_2/l à une valeur de sortie du bioréacteur conforme à la norme de rejet. Dans ce cas, la nature filamenteuse des boues produites ainsi que le temps de décantation apparaissent comme les principaux facteurs limitant la performance du procédé. Il est également apparu que l'élimination de la DCO dépend largement de la charge volumique (Cv) et de la charge massique (Cm) appliquées et de l'âge de boues. Pour une charge volumique appliquée allant de 0,075 à 2,52 kg DBO_5/m^3/j et une charge massique comprise entre 0,05 et 2 kg DBO_5/kg MVS/j, la performance du bioréacteur est inversement proportionnelle aux charges appliquées; elle oscille entre 80 et 99 % en fonction de Cv et entre 90 et 99 % en fonction de Cm. Le bioréacteur séquentiel est encore plus avantageux que le procédé à boues activées conventionnel qui nécessite 4,5 jours d'aération pour réduire une DCO appliquée de 6210 mgO_2/l, sans recyclage, avec une charges volumique comprises entre 0,29 to 0,92 kg BOD_5/m^3/j et une charge massiques allant de 0,05 et 2 kg DBO_5/kg MVS/j .

Mots clés: Effluents agro- alimentaire, effluents de laiterie, épuration biologique, traitement biologique séquentiel.

INTRODUCTION

In Algeria, many food industries, large water consumers, discharge their highly polluting liquid effluents directly in rivers incapable of assuring self treatment, especially in times of drought. This is the case of a dairy and cheese factory located in the region of Tizi-Ouzou (Algeria) which rejects an average of 1200 m^3/d of wastewater into the quasi permanent low flow water of the Sebaou river. These effluents, characterized by variability in flows and concentrations, constitute an essentially organic pollution in a dissolved form and easily biodegradable, estimated at 4.27 g COD / l. The pollution of these discharges, equivalent to 48000 inhabitants, corresponds to a 438.10^3 m^3/year outflow and an annual output of 1825 tons of organic matter (measured in COD). The treatment of these effluents will serve to protect the environment, to reuse purified water for irrigation and to valorize the resulting sludge in agriculture.

After having experimented the process with traditional activated sludge (Yahi & al, 2008, Yahi & al, 2009a et Yahi & al, 2009b), we present here the results of a sequencing batch bioreactor (SBR) whose principle is the same as the activated sludge but consists of airing then decanting the effluent volume in the same pool discontinuously fed by the effluent to be treated. This can be achieved in one or more cycles.

The purpose is the assessment of the sequencing batch reactor performance (SBR) on the carbon pollution elimination under the influence of the variation of the applied loads and the aeration time.

The tests were first carried out with model solutions obtained by diluting the milk produced by the dairy and then with the real effluent as rejected by the company in the receiving environment. In the case of synthetic samples, the COD content varied from 220 to 7000 mgO_2 / l corresponding to a charge density comprised between 0.075 and 2.52 kg DBO_5/m^3/d or 0.13 to 4.36 kg COD/m^3/d. The aeration time is varied from 16 to 48 hours.

REVIEW OF LITERATURE

The sequencing batch reactor (SBR) has been successfully applied by (Bouille et al 2005; Castillos de Campins, 2005; Corthondo et al, 2004; Dolle, 2003; Torrijos & al, 1997; Torrijos & al, 1998; Torrijos & al, 2003; Moletta et al 2004; Yahi et al, 2010) on dairy effluents, and by Merzouki, (2007) on lemonade factory's effluents. This process, which has the advantage of being compact, is particularly well suited for effluents batch production. According to Torrijos et al (1998), treatment with SBR on dairy effluents with a charge density of 0.51 kg COD/m^3.d, allows a reduction of 98 % of COD and 97 % of TSS.

In the field of treatment of dairy effluents and more generally of agro-food industry effluents, the comparison of different usable biological processes showed that the SBR is the most efficient (Castillos de Campins, 2005). The batch mode allows the coupling of the hydraulic residence time and of the sludge residence time, the reactor acting as a decanter. Indeed, SBR allows 99 % deduction of organic matter, 100 % of TSS, 94 % of nitrogen Kjeldahl and 87 % of total phosphorus.

In addition to the high treatment efficiency, SBR presents advantages of low investment and maintenance costs, scalability, adaptability and automation. According to (Corthondo et al, 2004 and Dolle, 2003), if the expenses related to the SBR installation are more advantageous, the operating costs are unfavorable (high energy consumption).

Castillo de Campins (2005) has studied the influence of the aeration cycle number and the tank bottom volume (stored sludge volume) between each treatment cycle on treatment performance in the case of very heavy loads applied from 1.7 to 5.4 kg $COD/m^3/d$. The reactor total volume is 2 liters and the tank bottom is 0.45 liter.

Biodegradability tests have been performed with various effluents models and elaborated with whole milk diluted 50 times amended or not.The incoming effluent presents gross COD contents from 2900 to 3675 mgO_2/l, a pH oscillating from 6.47 to 7.56 and TSS from 1.08 to 3.33g/l. The results on treated effluent show COD soluble values from 0 to 550 mgO_2/l, pH levels from 6.52 to 8.25 and TSS from 0.73 to 4.3g/l.

EXPERIMENTAL STUDY

Materials and methods

Materials

The reactor used consists of a single plexiglass basin of a total volume of 9 liters. It is connected to a "Bio-type aqualitic simulator" which is composed by:

- A feed pump for substrate,
- A pump for drawing off excess sludge,
- An air compressor for supplying oxygen for the biomass aeration through a fine bubble diffuser.

The basin is equipped by a paddle stirrer in order to homogenize the mixed liquor during the aeration, up to 50 rpm, helping to avoid deposits on the reactor walls without causing shear damage to the micro organisms and reduce their activity. Two specific probes immersed in the reactor allow continuously measuring the temperature, pH and dissolved oxygen content. The dissolved O_2 content may be changed at any time by changing the aeration rate and agitation speed. The experiments were performed at room temperature and without changing the pH.
The samples for analysis and the supernatant drain are siphoned off. The samples are primarily used to measure the evolution of the gross COD, TSS and pH. The sample volume required for analysis does not exceed 100 ml.

Methods

Characterization of the dairy' effluent

The average composition of waste given in Table (1) shows that the effluent has a very high organic load with COD and BOD_5 average respectively equal to 4270 mg/ l and 2460 mg/ l and maximum values up to 7500 mg COD / l and 480 mg BOD_5 / l.

If one considers that the average BOD_5 of domestic effluents is 300 mg/l, according to (Degremont, 2005), it appears that dairy effluent are about 8 times more concentrated. If one refers to the average values of COD and BOD_5 of whole milk produced by the dairy concerned, evaluated respectively at 133 g/l and 76 g/l, we can also consider that the wastewater of the dairy represents about 30 times diluted milk, table (2).

The average content of organic matter in the milk produced by the dairy, expressed as BOD_5, is less than that given by (Degremont, 2005) for milk, meaning about 100 g / l. According to (Dolle, 2003), the volume of wastewater discharged by dairies (white water + whey) is 4.2 liters per liter of produced milk and the COD is about 14 g/l of effluent.

Biodegradability coefficient, which closes 1.7, reflects the ability of biological treatment of these effluents. The presence of fats upsets the biological treatment of water because aerobic processes degrade fats only with slow kinetics.

Table 1. Average composition of the dairy's effluent (Yahi et al, 2008).

Parameters	Unities	Average value	Maximal values	Algerian standardvalues
Colour	/	White	/	/
Temperature	°C	25	30	30
pH	/	6	3 - 11	6,5 – 8,5
TSS	mg/l	587		30
BOD_5	mgO_2/l	2460	4800	40
COD	mgO_2/l	4270	7500	120
COD/BOD_5	/	1,73		
Fat materials	mg/l	120		
N Total	mg/l	150		40
N (NH_4^+)	mg/l	8,47		
N (NO_3^-)	mg/l	20.45		
P total	mg/l	90		2
$(PO_4)^{3-}$	mg/l	21		

Table 2. Average values of parameters of the milk produced by the dairy (Yahi & al, 2008).

pH	BOD_5 (g/l)	COD (g/l)	NH_4^+ (mg/l)	NO_3^- (mg/l)	PO_4^{3-} (mg/l)
7,4	76.00	133.00	62.71	408.85	435.71

The pH of the effluent is characterized by large variations which can reach extreme values of 3 and 11. Because of its high content of lactose, wastewater moves, with an extreme rapidity, to the state of acid formation. In this process, called lactic acid fermentation, under anaerobic conditions, there is decomposition by Bacillus lacticus of the lactose and lactic acid formation by the following reaction:

$$C_{12}H_{22}O_{11} + H_2O \rightarrow 2\ C_6H_{12}O_6 = 4\ C_3H_6O_3. \qquad (1)$$

Synthetic effluent

In order to represent the wastewater generated by the dairy, effluent samples were prepared from the milk produced by this dairy proceeding by diluting it with water of the supply network of drinking water without adding any other product, including acidic or basic reagents used in cleaning operations.

The use of synthetic effluent (diluted milk) is justified, on one hand, by the technical difficulties related to the collection and transport of samples, and on the other hand, by the experimental need to work with controllable effluent of constant composition. Dairy effluents are often variable over time (rates, charges, pH, suspended solids, fats ...).

Dairies effluents are considered almost like whole milk diluted. In principle, they contain only milk elements, mainly albumin, undissolved particles of fats, lactose, nitrogen and phosphorus, Table (1). As the organic load (COD and BOD_5) of produced milk varies daily, analyzes were performed on each packet of milk before use, in order to better control the amount of organic material fed into the reactor.

Seeding of the reactor

The seeding of the reactor was carried out with biomass coming from the wastewater treatment plant of Tizi-Ouzou, according to the protocol described by [Castillo De Campins, 2005]. The sludge is collected in the aeration basin. Its TSS concentration varies from 4 to 10 g / l. It is aerated for 2 hours so that the microorganisms remove the most party of the substrate remaining in the endogenous area. The sludge is then centrifuged during 10 minutes. The masses of fresh sludge used to seed the SBR vary from 10 to 20 g. Acclimatization of fresh mud into the milk substrate was made discontinuously by injecting into the aeration basin increasing doses of synthetic effluents. The adaptation of the biomass to the new substrate, which lasted a few days, resulted in a change of the color of the mud from gray to brown.

Methods of analysis

The evaluation of the treatment performance of the biological reactor consists to measure, input and output, temperature, pH, TSS, MVS, COD and BOD_5. The used analytical methods are given by [Degremont, 2005].

Implementation of the essays

The block diagram of the SBR is shown in Figure (1).

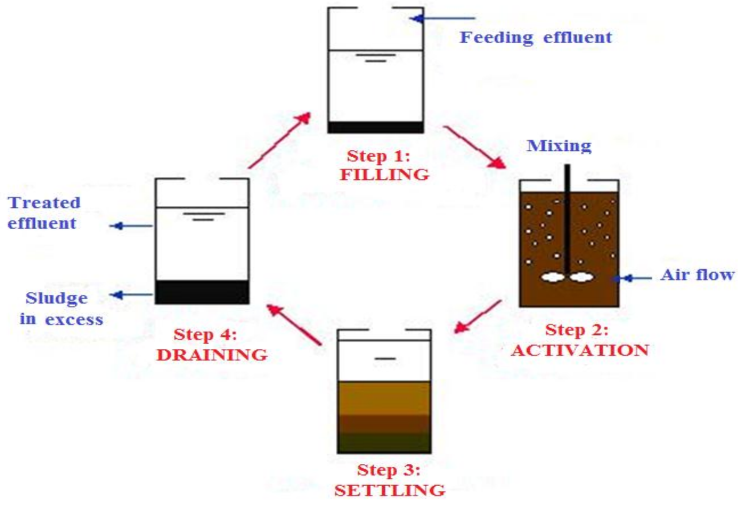

Fig. 1. Block diagram of the SBR (Castillo De Campins, 2005).

After having been sown, the reactor is first filled in a single step with 2 to 3 liters of the synthetic effluent which will be treated.
It is then aerated and agitated for a predetermined time (inconstant).
It is finally subjected to a settling for a constant time (two hours).

The obtained supernatant is then characterized in order to evaluate the treatment performance of the process before being drained. According to the biomass content which we want to obtain in the reactor, settled sludge can be partially withdrawn to maintain a corresponding starter. All these operations represent a course of treatment.

Each experimental test corresponds to a single cycle of operation previously preceded by the total drain of the supernatant; only the sludge in the reactor is kept at a level between 1 and 2 liters, meaning 20 to 40 % of the useful volume. Table (3) summarizes the operating conditions of all tests.

The reactor's performances are determined under the influence of the variation of the organic load of the effluent which will be treated, time of aeration and the biomass concentration in the reactor.

These variables are correlated by the two following operating parameters:

The volumetric load, which is written: $Cv = S_0 .Q/V$ (2)

The mass load, which is written: $C_m = S_0 .Q/VX$ (3)

C_V in (kg $BOD_5/m^3/d$)

C_m in (kg BOD_5 /kg MVS /d)

S_0 = applied organic concentration (kg BOD_5/ m^3)
Q = effluent flow (m^3/d)
V = useful volume of the reactor (m^3)
X = biomass concentration in the reactor (kg MVS/m^3).

Table 3. Main operating parameters of the reactor

Parameters	Values	Unities
Total volume	3 to 5	l
Treated volume	2 to 3	l
Starter (settled sludge)	1 to 2	l
Aeration time	16 to 48	h
TSS (Total solids concentration in the reactor)	0.72 to 5.8	g/l
Applied BOD_5	127 to 04,6	mg /l
Applied COD	220 to 7000	mg/l
Volumetric loading (Cv)	0.075 to 2.52 0.130 to 4.36	kg BOD_5 / m^3/ d kg COD / $m^{3.}$/d
Organic Mass loading (Cm)	0.05 to 2 0.08 to 3,46	kg$BOD_{5/}$ kgMVS/d kgCOD / kgMVS/d
Dissolved oxygene content	2 to 5	mg/l
pH	7,02 to 7,96	/
Temperature	20 ±5	°C

RESULTS AND DISCUSSION

Influence of aeration time and DCO concentration

Figures (2), (3) and (4) show that, whatever the input COD concentration of the effluent varies from 220 to 7000 mg / l, the residual COD of the purified effluent is reduced when the time of aeration increases. In general, there is an initial phase of rapid degradation up to 20 hours of aeration, without any latency period, followed by a slowdown.

For low concentrations of input COD (220 - 2640 mg / l) of the synthetic effluent, an aeration time of 20 hours is sufficient to ensure a composition effluent which largely complies with rejection standards, figure (2). The same result is obtained by treating the real effluent rejected by the dairy, figure (3).

This aeration time corresponds to that of the SBR treating dairy effluent to 12 g COD/l, based on (Bouille et al, 2003). This result shows that the choice of a sequencing batch reactor is more advantageous than the conventional activated sludge process used by (Yahi et al, 2008) and (Yahi et al, 2009a), which required 24 hours of ventilation with 100 % recycling to eliminate only 1250 mg COD / l.

For more important value of applied COD (3120 - 7000 mg / l), the required aeration time is more important too. Thus, it takes 48 hours of aeration to reduce 7000 mg of COD / l to a value close to 120 mg / l, barely compliant to discharge standard, Figure (4). However, this time of aeration obtained by a SBR is significantly lower than the 4.5 days of ventilation required by the activated sludge process experienced by (Yahi et al, 2009b) to treat dairy effluent of 6210 mg COD/ l.

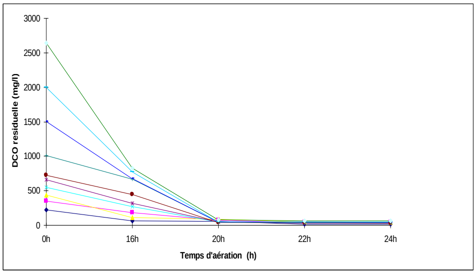

Fig. 2. Aeration time effects on a residual COD

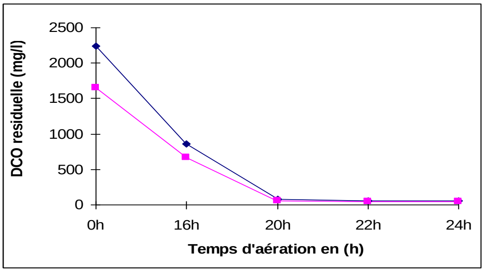

Fig. 3. Aeration time effects on a real effluent residual COD.

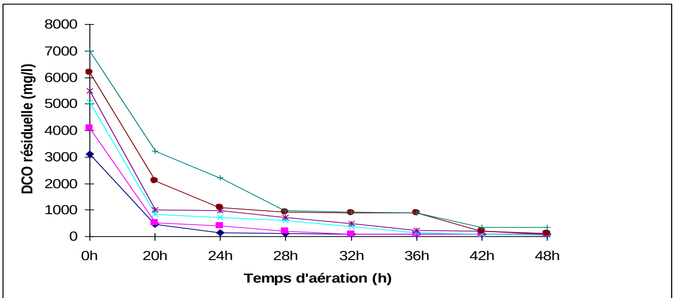

Fig. 4. Aeration time effects on a residual COD.

Volumetric loading effects (Cv)

Tests are performed with volumetric load from 0.075 to 2.52 kg BOD_5 / m3/d, corresponding to 0130 to 4.36 kg COD/m^3.

Figure (5) shows that the residual COD is an exponential function of the volumetric load up to 2.52 kg DBO_5 / m^3/d. Beyond 1.2 kg BOD_5 / m^3/d, the residual COD exceeds discharge standard. Figure (6) shows that the removal efficiency of organic pollution is greater than 95 % in average charges (Cv ≤ 1 kg BOD_5 / m^3/d). For a applied load COD of 7000 mg / l, the efficiency is around 98 % and the volumetric load corresponds to 1.2 kg BOD_5 / l.

This high efficiency corresponds to the one reported by [Corthondo et al, 2004], [Torrijos et al, 1998] and [Moletta et al, 1999] . However, these performances appear higher than those obtained by [Castillo De Campins, 2005] on treatment with a SBR on a similar effluent giving a input COD between 2900 and 3675 mg / l corresponding to a volumetric load between 1.7 and 5.4 kg COD / m^3/d

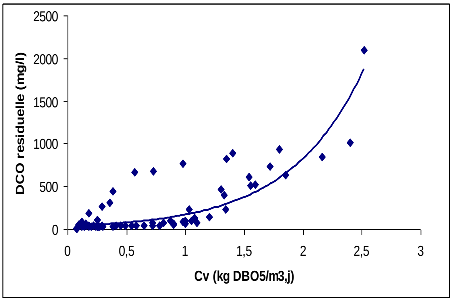

Fig. 5. Volumetric loading effects on a residual COD.

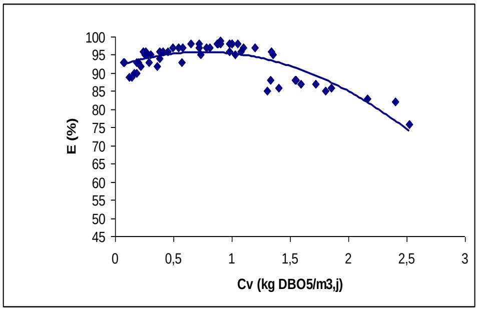

Fig. 6. Volumetric loading effects on treatment efficiency by COD.

The experiment carried out by Castillo De Campins (2005s) took place over 248 hours with 15 cycles performed on a sequence average of 10 hours of aeration and1.5 hour of settling. The values of soluble COD raised at the end of the cycle are generally of the order of 300 mg/ l; they are superior to the standard of discharge and do not provide effluents sufficiently clarified due to settling difficulties.

Organic mass loading effects (Cm)

Figure (7) shows that the COD of the treated effluent increases significantly with the value of the applied mass load beyond 0.25 kg DBO_5/ kg MVS/d. The efficiency of the process that closes the 100 % decreases from a value of 1.2 kg BOD5 / kg MVS/d, Figure (8).

TSS content in the bioreactor is controlled by the level of the starter maintained between two successive draining of the supernatant.

According to the tests, it has fluctuated between 0.5 and 5.8 g / l. In the absence of withdrawal, it mainly depends on the growth of the purifying biomass and the effluent nature. When the applied COD load becomes important, TSS control becomes difficult because of the bad settling of the sludge that remains in the supernatant after the settling phase. The settling time becomes, then, the main factor influencing the performance of the process. A swelling phenomenon sludge, characterized by a high Mohlman index (≥ 150), was observed.

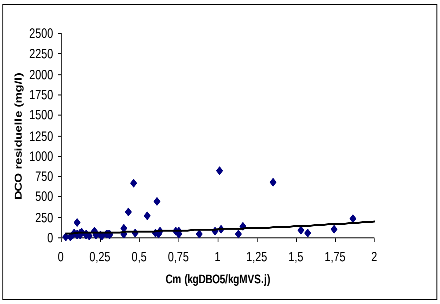

Fig. 7. Organic mass loading effects on a residual COD

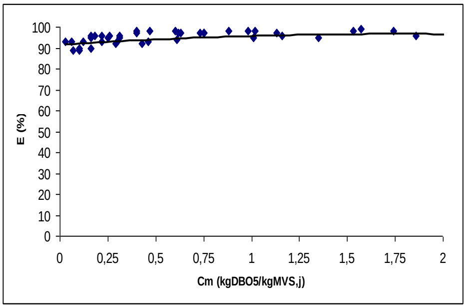

Fig. 8. Organic mass loading effects on treatment efficiency by COD.

CONCLUSION

The results show that the use of he sequencing batch reactor (SBR) is adapted for the elimination of the strong carbon pollution, easily biodegradable, of the dairy's effluents. Indeed, with 48 hours aeration time,2 hours decanting and a starter maintained between20 and 40 %of the useful volume, the SBR can treat up to7000 mg /l COD effluent according to rejection standards, meaning 98 % of efficiency.

The settling time, set at 2 hours, limits sludge settling and does not remove more than1.2 $kgDBO_5$ $/m^3/d$, meaning about 2 kg COD $/m^3/d$.

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