TRANSITORY FLOW RBC PROCESS WITH BIOMASS AND SUPPORT REMOVAL

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ABSTRACT

The biofilm and support are removed when a certain thickness is achieved (BE process). This action modifies the RBC process, so that the biomass growth follows a transitory phase. Therefore, the BE process is able to support higher organic loads than those conventionally designed. This way, process failure due to support obstruction is avoided. In this work, a four stages-artificial wastewater feed (made aut of glucose)-laboratory RBC has been analyzed. The RBC worked under an organic load between 8 and 66 g COD/m^2.d and hydraulic loading between 20 and 164 L/m^2.d. The hydraulikc retention time (HTR) varied between 30 minutes and 4 hours, and COD influent concentration between 100 and 1600 mg COD/L. The process works properly for concentrations lower than 400 mg COD/L. However, certain functional failures occur due to non-advantageous dominant populations (there was a decrease of the depuration capacity and the pH values dropped below 5) for COD influent concentration higher than 800 mg/L. COD removals higher than 94% can be obtained for influent loads up to 33 g COD/m^2.d. Organic load removal of 47 g COD/m^2.d was achieved for influent loads of 66 g COD/m^2.d.

KEYWORDS

biofilm process; RBC; non steady state; biofilm thickness control; cell retention time control

INTRODUCTION

Classic biofilm processes such as trickling filters and RBC have certain limitations because the biomass is not completely mixed. One of these limitations is the inability to artificially control the biomass, which is self controlled by the process itself. Excessive sludge growth can nullify the process as well as the affluent load (for example in the first stage of RBC) which conditions the system's design. The different biofilm processes use various methods to try to resolve the problem imposed by these limitations: recirculating the trickling filters, washing the aerated biofilters, limiting the functional load in all the processes or the maximum load in the first stage of biodiscs.

With the aim of obtaining an improved or advantageous biofilm process we consider the following objectives to be within reach: working with high loads (therefore reducing the size of the classic units); controlling the biomass, thus enabling an artificial sludge purge; eliminating the need for secondary decantation, thus reducing capital costs; greater oxygen transfer efficiency and therefore lowering energy consumption and facilitating or simplifying the treatment of sludge.

With this end in mind we have developed the "BE" process (Biopelícula Extraíble (Extractable Biofilm)). This could be defined as "A biofilm process in which the biomass may be controlled by artificially purging the sludge from the system. This is done by directly extracting the support (with its corresponding biofilm), parcially or totally treating the sludge while still on its support, and in that way facilitating the overall treatment process".

This BE process is capable of attaining the previously mentioned objectives. For example, any quantity of biomass may be extracted by taking out the necessary amount of support, thereby artificially controlling the biomass and thus avoiding excessive accumulations which reduce the efficiency of the process. It may be possible to excede the initial maximum load limitation for the process which may be able to work with greater loads and at the same time be smaller than its conventional counterparts. By controlling biomass growth, we can avoid it reaching a balanced thickness where growth is equal to loss and thus avoid the situation where the sludge produced passes into the effluent thus eliminating secondary decantation. As the purged sludge is directly taken from the support, squeezing out the water would provide a high concentration of solids. In this way the thickness objectives would be met. There are many simplified systems for treating the sludge extracted on the support, such as aerobic digestion, composting, natural dehydration, natural drying, etc.

In order to resolve the possible problems implied by working with the BE process a study has been performed on its viability, using a pilot plant of the RBC system. The following factors, among others, were checked: whether the process functions in a transitory regime with respect to the biomass, whether the periodic and intermitent extraction of the biomass produces an instantaneous overload and, therefore, an inadmissibly large variation in the quality of the process effluent (Stability of the effluent). A study was also made on the suitability of the suspended solids concentration obtained in the effluent to eliminate the secondary decantation and if the sludge treatment on the supports was apropriate. The kinetics of biofilm growth were analysed along with the elimination of organic material, carbon and nitrogen, evolution of pH and the concentration of SS in the effluent. The drying kinetics of the extracted biofilm were also studied.

METHODOLOGY

A pilot plant of biodiscs has been designed and constructed in perspex to be capable of satisfying the requirements demanded by the BE process. The plant consists of four stages. Each stage with twelve 180 mm diameter discs and a 2.1 L tank. A total surface area of 2.44 m^2 is provided for biofilm growth along with a total volume of 8.4 L. The four axles with the discs rotate against the flow of the water, moved by a motorized regulating system at a constant speed of 16 rpm (peripheral velocity of 0.15 m/s). 40% of the discs' area is submerged in the water to be treated.

An artificial waste water has been designed to feed the pilot plant. The constant composition of this water contains, among other components: glucose as a souce of carbon, NH_4Cl as nitrogen supply, it is buffered at pH 7 with phosphates ($Na_2H\ PO_4$ and KH_2PO_4), there are no suspended solids and it is at room temperature. This water is dosified to the plant by peristaltic pumps. For each experiment the influent flows were maintained constant as well as the concentrations of their components.

The experimental plan includes ample ranges for the working variables, as follows: applied organic load (AOL) from 9.3 to 77.2 g COD/m^2d; applied nitrogen load (ANL) from 0.7 to 5.4 g N-NH_4^+/m^2d; influent concentration (IC) from 100 to 1600 mg COD/L and from 8.8 to 131 mg N-NH_4^+/L; hydraulic load (HL) from 20.5 to 164 L/m^2d; and hydraulic retention time (HRT) from 0.5 to 4 h. With these characteristics, the following limit conditions exist for the first stage: organic loading of 308.8 g COD/m^2d; hydraulic retention time of 7.5 min. and hydraulic load of 656 l/m^2d.

Two different methods have been employed for extracting the biodiscs with the bimass in excess (sludge): advance (the first stage is extracted, all stages are moved one step forward and the last stage is replaced); and substitution (the stage with the most biofilm is extracted and substituted by clean discs).

Drying at room temperature has been studied for sludges extracted without separating them from the supporting medium, in this case the perspex discs of the RBC.

RESULTS AND DISCUSSION

The reactor works in a transitory state, of continuous biofilm growth (Fig. 1). This has direct repercussions on the quantity of organic matter removed in each stage, the first stage reduces its efficiency as the stages advance. As large quantities of biomass are removed the reduction in efficiency may even reach the effluent (Fig. 2).

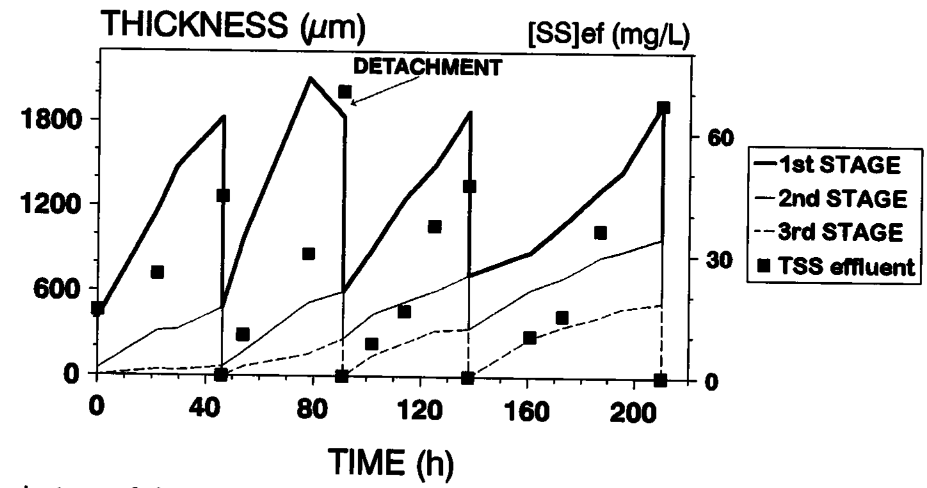


Fig. 1. Evolution of the thickness and effluent suspended solids during the BE process with advance system operation.

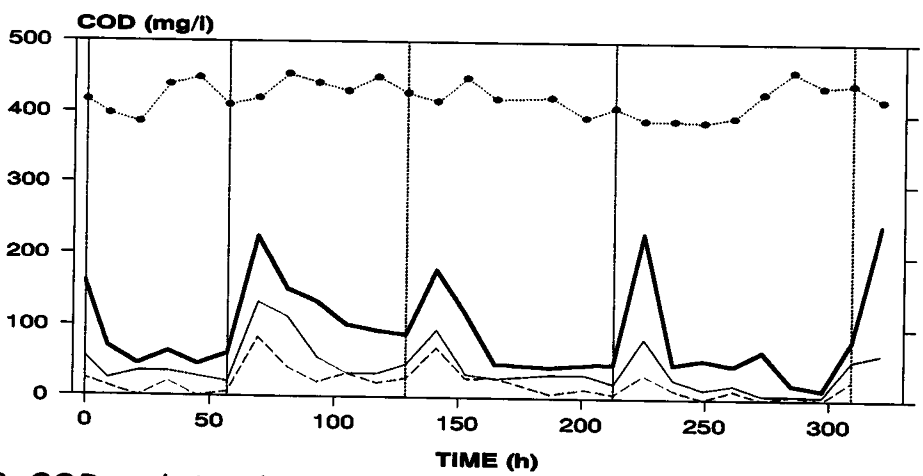


Fig. 2. COD evolution during the BE process with advance system operation

The efficiency of COD removal drops lightly with the increase in AOL. High levels of COD removal (over 80%) were observed for all experiments, even those where the process failed, but not for the overloaded experiment (removal of 61%). The biokinetic constants (Ks and P_{MAX}) (Fig. 3) of the Blackman model have been obtained for each stage. A high gradient is observed for the elimination of substrate during the first stage, this is owing to the use of easily oxidised glucose as a source of carbon (Harremöes, 1982). The efficiency of amoniacal nitrogen removal is similar in all the experiments performed (41 to 54%), independently of the applied organic load or influent COD or nitrogen concentration. Thus, the nitrogen is removed by celular assimilation.

In most cases, the evolution of the pH was as expected, a reduction of between one and two pH units during the first phase (owing to CO_2 formed during the complete oxidation of the organic matter) and a progressive increase in the pH during later stages, up to levels of 6.8 to 7.5 in the effluent. But in some experiments (where the process fails) the reduction in the pH is of 3 to 4 units and later increase up to neutral pH is not noticed in the following stages. pH values of less than 5 were observed in the effluent.

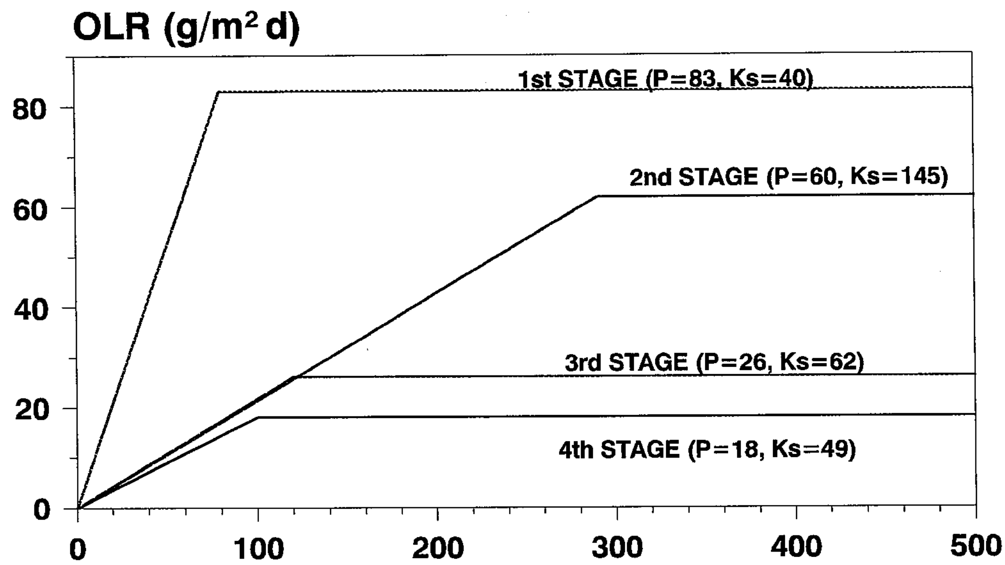


Fig. 3. BE process advance operation system Biokinetics by the Blackman fit

The extractable biofilm process (applied to a RBC process) is viable, with a confidence level of 0.9 in the experiments with influent COD of 470 mg/L and AOL of 32 g COD/m^2d (typical concentrations for wastewater), reaching organic matter removal efficiencies of over 90% in COD. However, with influent COD of 800 mg/L and AOL < 32 g COD/m^2d, the process fails (it is not viable) because of the predominance of microbian populations in the biofilm which acidify the medium and reduce its efficiency. With AOL > 77.2 g COD/m^2d the process does not fail, but it is overloaded and not capable of reaching 90% of COD removal (Fig. 4).

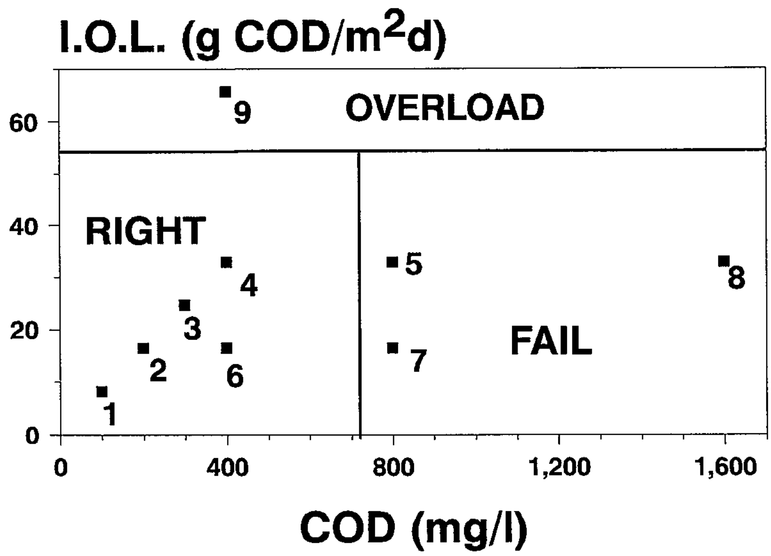
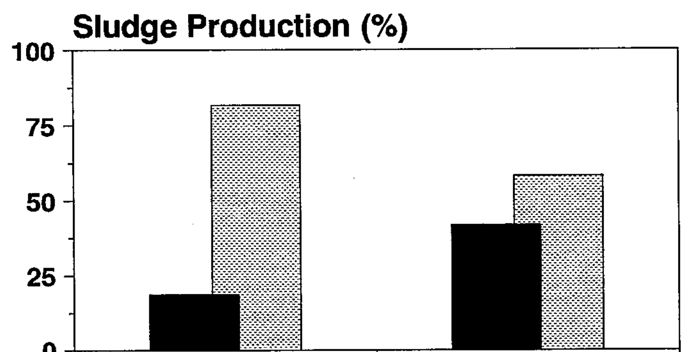


Fig. 4. Performance of the BE process with advance system operation. Influence of applied organic loading and influent COD.

The effluent's SS concentrations are less than those presented by the conventional RBCs, although in some occasions after biofilm slaughing high SS concentrations were found. (Fig. 1) Biofilm density showed an average value of 23 g/L, very similar in all the experiments and is therefore independent of the working conditions.

The two types of biofilm extraction systems have shown that both oxidise the same quantity of carbon, producing a similar quantity of sludge. With the stage advance system, the greater part of the produced biomass is extracted with the discs. When the RBC was operated by substitution system, the effluent's SS result in almost half of the total sludge produced, thus, the effluent COD and N are greater in the substitution system, and the growth of the biofilm is greater in the advance system (Fig. 5). Drying of extracted sludge has been quick and high, owing to the large surface area and low thickness of the biofilm. A dryness of 90% has been obtained after 48 hours.



	ADVANCEMENT	SUBSTITUTION
Sludge Prod. (g/d)	17.6	17.7
effluent SS (%) ■	18.5	41.8
SS in support (%) ▒	81.5	58.2

Fig. 5. Comparison between both BE process operation systems in respect of the sludge production in the effluent and in the support.

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