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The kinetics of self-aerated biofilms in a hollow fibre biomembrane reactor

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INTRODUCTION

This paper describes the kinetics of removal of organic matter from wastewater carried out by means of a self-aired biofilm in a hollow fibre biomembrane reactor. The biofilm is aerobic, therefore, it absorbs oxygen for its growth through the hollow fibres full of air at atmospheric pressure and it consumes the substratum from the liquid medium. The mobility of the micro-organisms generates turbulence in the biofilm, turning into a transport mechanism of additional mass known as bioturbulent.

The aims of this research were: 1) to observe the kinetics of organic elimination of a self-aired biofilm which takes place in a hollow fibre biomembrane reactor and 2) to evaluate the transfer of oxygen by the self-aeration of the film, that is, owing to a biologically improved transfer.

MATERIALS AND METHODS

A laboratory scale biomembrane reactor was constructed and operated with an inlet liquid stream containing glucose, which served as a carbon source. The biomembrane reactor was constructed of methacrylate with a width of 5 mm and a diameter of less than 90 mm.

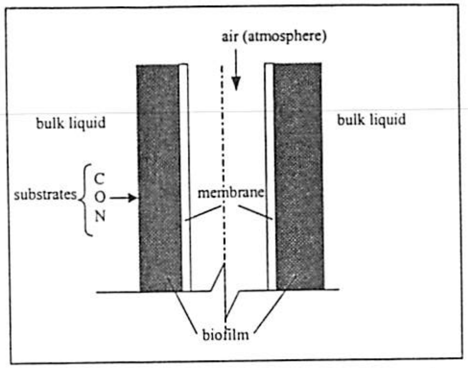

Figure 1. Longitudinal section of a hollow fibre with biofilm.

The supporting membrane consisted of 8 hollow fibres of polypropylene (Accurel® PP) with pores of 0.20 µm, bubble point of 0.95 bar, thickness of 450 µm and internal diameter of 1800 µm. The effective volume of the reactor was 1.4 litres, and the damp surface of the fibres was 0.036 m^2. One end of the hollow fibres remained exposed to the atmosphere. The global oxygen transfer coefficient was measured, K, (hollow fibre without biofilm + liquid diffusion layer) through a typical aeration test of deoxygenated water in a transient state. The average value of K was 0.018 m/h. Therefore, the oxygenation capacity of the reactor was of 4.3 g O_2 m^{-2} d^{-1}.

The reactor was operated during 10 months under different operational conditions. The organic load applied fluctuated between 10 and 450 g COD m^{-2} d^{-1}. The influent COD concentration ranged from 8 to 370 mg/L. The dissolved oxygen, DO, in the liquid medium was always above or equal to 2 mg/L. Thus, denitrification was inhibited. The monitoring of the process also included measurements of forms of nitrogen (ammonium, nitrite, and nitrate).

RESULTS AND DISCUSSION

With a homogeneous growth of the biofilm, the eliminated organic load followed a saturation function in relation to the applied load (eq. 1 and fig. 2):

$$r_A = r_{A,max}\,\frac{B_A}{K_B + B_A} \qquad (1)$$

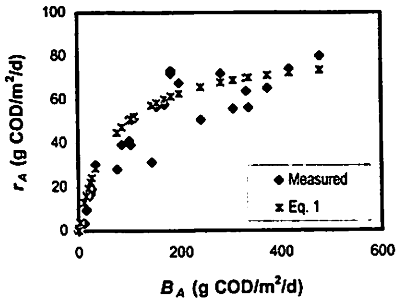

Figure 2. Kinetics of removal of COD.

Where B_A = applied organic load (g COD m^{-2} d^{-1}); r_A = removed organic load (g COD m^{-2} d^{-1}); $r_{A,max}$ = maximum organic load removed (g COD m^{-2} d^{-1}); K_B = organic load applied for which r_A = ½ $r_{A,\ max}$ (g COD m^{-2} d^{-1}). The deduced values for $r_{A,\ max}$ and K_B were 83.3 and 65, respectively.

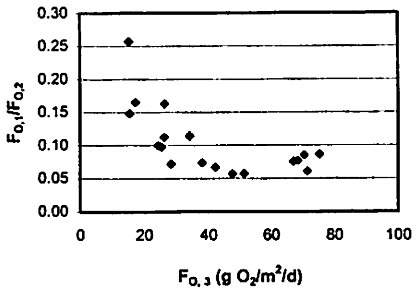

Figure 3. Ratio $F_{O,1}/F_{O,2}$ dicreases as $F_{O,3}$ rises.

The total surface flux of consumed oxygen $F_{O,3}$ (g O_2 m^{-2} d^{-1}) was calculated by means of mass balances based on the stoichiometry of the heterotrophic an autotrophic growths. The mechanism of oxygen transfer is a function of $F_{O,3}$. When $F_{O,3}$ increases to very high values the diffusion of oxygen from the liquid medium has very little significance in the face of the biologically improved transfer through the pores of the hollow fibres. The global flux of consumed oxygen has an influence on the ratio between the transport mechanisms $F_{O,1}/F_{O,2}$; where $F_{O,1}$ = flux of oxygen from the water medium (g O_2 m^{-2} d^{-1}); $F_{O,2}$ = flux of oxygen through the hollow fibres (g O_2 m^{-2} d^{-1}). This ratio varies from 0.25 (at $F_{O,3}$ = 15 g O_2 m^{-2} d^{-1}) to an asymptote = 0.075 (at $F_{O,3} \geq 50$ g O_2 m^{-2} d^{-1}) (fig 3).

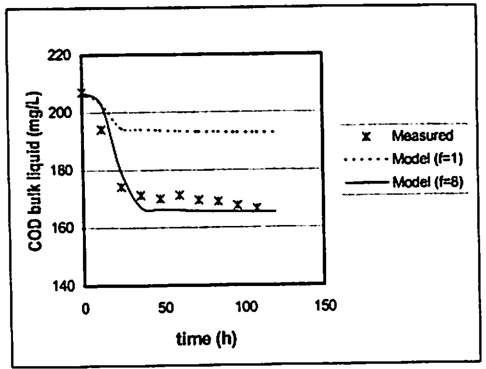

Figure 4. Numerical simulation of the process with AQUASIM programme.

The numerical simulation of the process was carried out with the aid of the AQUASIM programme. The adjustment considered the effect of the biologically improved transfer of oxygen by means of an *f* coefficient, if this effect is not taken into account ($f \leq 1$), a good adjustment of the model is not achieved. In the case at point (fig. 4) *f* reached a value of 8 to obtain a better adjustment. The concentration of the biofilm was of 78 g/L as COD.

CONCLUSIONS

In a biomembrane reactor without artificial aeration an aerobic biofilm is viable for the oxidation of organic matter and ammonium. The magnitude of this oxidation is a direct function of the applied oxidable load. If the organic load removed is approximately 40 g COD m^{-2} d^{-1} 90% of the global performance of the process, this is due to the self-aeration by a biologically improved transfer of oxygen. The maximum organic load eliminated was approximately 83 g COD m^{-2} d^{-1}. The oxygenation capacity of a biomembrane reactor can be biologically improved. Without a biofilm, the atmospheric pressure aeration of the hollow fibres is 4 g O_2 m^{-2} d^{-1} whereas with a biofilm the aeration is increased by a magnitude order from 40 to 80 g O_2 m^{-2} d^{-1}.