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Hollow fiber membrane ultrafiltration of a simulated secondary treatment wastewater. Process and fouling modeling

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Introduction

It is well known that there is a scarcity of drinking and irrigation water around the world nowadays. According to the United Nations, water scarcity affects 1.2 billion people (one-fifth of the world's population) and the water use has been growing at twice the rate of population increase in the last century.

This fact makes the reuse of the wastewater from municipal wastewater treatment plants (MWTPs) an interesting option. Ultrafiltration after the secondary settling is becoming more frequently used for wastewater reclamation and it has some advantages compared with conventional processes such as compact design and high quality of the final effluent (including microbiological parameters). However, membrane fouling aspects have to be more deeply studied in view to a more prolonged membrane life. For it, modeling of the process is of crucial importance. Thus, the effect of the operating conditions in the ultrafiltration membrane fouling has been reported by several authors in the bibliography (Wang et alter [1]).

In this work, a hollow fiber membrane module has been applied to the ultrafiltration of a simulated secondary effluent from a MWTP. The water quality and the membrane fouling were investigated. This work is focused on the effect of transmembrane pressure and the cross-flow velocity on membrane permeability.

In addition, in order to model the ultrafiltration fouling process, permeate flux versus time data has been fitted to a Belfort model (see expression below) (Mallubhotla and Belfort [2])

$$J(t) = J_{t=0} \cdot e^{\frac{-t}{A+B\cdot t}} \qquad \text{(Belfort flux decline model)}$$

Material and methods.

Tests were carried out in an ultrafiltration pilot plant using synthetic water; this water mimics the secondary treatment effluent composition. In order to prepare this water, a protein (Bovine serum albumin, BSA) and a carbohydrate/polysaccharide (Dextran) were added to tap water. These compounds were selected due to the fact that proteins and polysaccharides have been reported to be the key components in the extracellular polymeric substances (EPS) that are solubilized from the biomass in the effluent. (Susanto e alter [3]).

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The *pilot plant* used is a modified Norit X-flow T/RX-300 commercial test unit. Pressure sensors, a flowmeter (in the permeate outlet) and a temperature probe (inside the tank) have been added. The plant is controlled by a programmable logic controller. See the Figure 1.

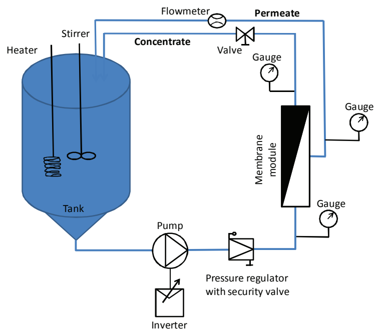

Figure 1. Scheme of the pilot plant.

The *reagents* used were BSA (bobine serum albumin, a protein) from Sigma-Aldrich (MW: 66.430 g/mol) and dextran (250KDa, a carbohydrate) from VWR International Ltd.

The *membrane* used is a UFCM5 commercial ultrafiltration membrane manufactured by Norit X-flow. It is made of a blend of polyethersulfone and polyvinylpyrolidone. It is hydrophilic and its molecular weight cut off (MWCO) is 200 KDa. It is a hollow fiber membrane and the configuration used is inside-out.

So as to analyze the effect of the operating parameters onto the water quality and onto the membrane fouling, different transmembrane pressures and different cross-flow velocities were tested. The temperature was kept constant during the tests.

Each test lasted about 9 hours, and the concentrate and permeate were both recirculated back to the feed tank. The transmembrane pressure, the permeate flow and the temperature were registered by a PLC.

Results.

In order to compare, three tests (NC2, NC5 and NC8) with the same cross-flow velocity (CFV 0.75m/s) but different transmembrane pressure (TMP 0.1, 0.15, 0.2 MPa) have been selected. Their flux decline (permeate flux versus time) is shown in Figure 2. In this work, the dimensionless flux is defined as the flux divided by the initial flux, defined the latter as the permeability of the clean membrane multiplied by the pressure of the test. On the other hand, as an example of the fouling modeling, Figure 3 shows the fitted Belfort model for the test Id. NC5 data.

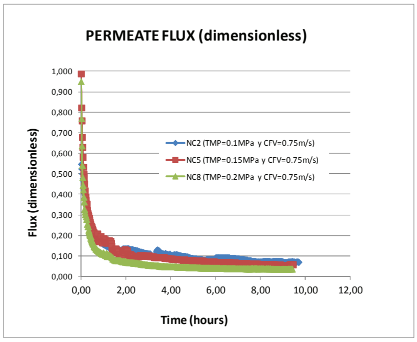

Figure 3. Fitted Belfort model.

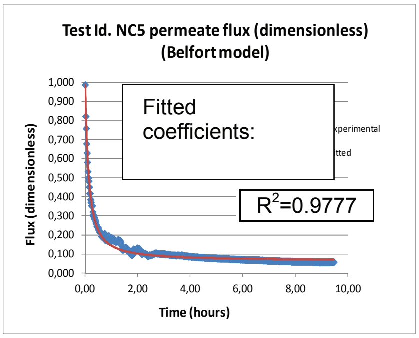

Figure 2. Flux decline.

A fast permeate flux reduction (fouling) is observed shortly after the start of the tests, and a steady-state is achieved after 8-9 hours. As expected, the higher the transmembrane pressure the faster the fouling (see figure 2).

Experimental data (permeate flux) can be adjusted to a Belfort model obtaining a good fitting. As an example, Figure 3 shows the experimental data and the adjusted model of one of the tests (test id. NC5).

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