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ScienceDirect
Desalination 245 (2009) 314–320
DESALINATION
www.elsevier.com/locate/desal

Optimization of a nanofiltration membrane process for tomato industry wastewater effluent treatment

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Received 28 June 2007; Accepted 20 May 2008

Abstract

The wastewater stream produced during tomato manufacturing is characterized by a dark color and bad smell, and is heavily polluted by organics, suspended solids and ground particles. The concentration of pollutants in the effluent can vary considerably with time and space due to the changes in the harvested fruit composition and season. A discharge in the municipal sewage system of these streams is not directly possible because of the high organic contents above the legally tolerated limits. This work deals with the treatment and purification of the wastewater stream from the tomato industry by a biological pretreatment step and a batch nanofiltration process step. For the latter, critical fluxes were measured at different recovery levels. This permits applying membrane process optimization methods based on the critical flux. The experiments show that the purification of the wastewater up to a water compatible with the municipal sewer system requirements is possible, with a recovery rate of 90%. Short-term fouling issues may be avoided at permeate fluxes about or below 8.2 l h^{-1} m^2.

Keywords: Wastewater; Nanofiltration; Optimization; Fouling; Tomato

1. Introduction

The tomato industry produces huge amounts of wastewater effluents during tomato manufacturing towards canned products such as tomato concentrate and tomato pulp [1]. For instance, these effluents are generated during the cleaning, sorting and moving of the processed tomatoes [2]. The wastewater stream is characterized by a dark color and foul smell since it is heavily polluted by organics, suspended solids and ground particles [3].

The average amount of wastewater exiting a medium-sized tomato industry is about 300 m^3/d. The reduction of fouling on the membranes is one of the main challenges of the recently broadly applied membrane technology. Fouling causes

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0011-9164/09/$– See front matter
doi:10.1016/j.desal.2008.05.028

both a smaller productivity and a shortened life of the membranes. The practice of the critical flux seems to be one of the most used approaches to overcome fouling problems. At the critical flux point the drag forces on the solute molecules concentrated over the membrane surface are equal to the dispersive forces, leading to a steady state layer in gel state. In these conditions, only reversible fouling can occur, which can be periodically soft-cleaned.

Field et al. [4] introduced the concept of critical flux for microfiltration, stating that there is a permeate flux below which fouling is not observed. It was immediately clear that the newly developed concept was a very powerful optimization tool for this kind of separation operation. Afterwards, it was possible to identify a critical flux for UF and NF membranes [5].

However, some authors [6] pointed out that operating below the critical flux may not be sufficient to avoid long-term fouling. These authors introduced the concept of sustainable flux, at which the desired separation can be operated in profitable manner, only minimizing and not eliminating fouling at all.

The main drawback of the concept is that nowadays the determination of the best permeate flux cannot be theoretically predicted, but only experimentally measured. Critical flux depends on various factors, such as hydrodynamics [7] and feed stream composition [8]. The first factor is difficult the scale-up from laboratory plant to pilot and industrial plant, since at different scales membrane modules of different size are used and thus different hydrodynamic conditions are attained. The change in the feed stream compositions occurring throughout a batch operation increases the difficulty to apply the critical flux concept to batch processes since the critical conditions are related to the instantaneous solute concentration.

All the above considerations lead to the necessity of carrying out experimental work for any specific separation process in order to identify the best practice in presence of fouling. In this work, the fouling of spiral-wound membrane modules for a batch separation process for the treatment of tomato canneries was investigated in order to develop the best practice strategy. The process consists of a biological pretreatment step and a batch nanofiltration process step (NF).

Firstly, the critical flux values were experimentally determined at various feed stock pollutant concentrations. Then, the best operating practice for the process was identified by using a simulation model developed by Stoller and Chianese for the evaluation of the performances of the overall process [9]. Finally, it was checked that at the optimized operating condition no short-term fouling occurs.

2. Experimental set-up

A sample from the biologically pretreated effluent taken at an Italian tomato industry site was analyzed in order to determine the wastewater composition. The characteristics of this feedstock are reported in Table 1.

A scheme of the pilot plant is schematically represented in Fig. 1. The plant consists of a 100-L feed tank (FT1) in which the pretreated feedstock is carried. The centrifugal booster pump (P1) (Ebala CDM70/12, 0.9 kW) and the volumetric pump (P2) (piston pump, Idromeccanica C832PP, 7.5 kW, max. 50 bar) drive the wastewater stream over the spiral-wound membrane modules fitted in the housing (M1). The piston pump has on the outlet pipe a CO_2

Table 1
Typical composition of the real wastewater stream

Parameter	Value
pH	6.62
Conductibility, mS/cm	2.56
COD, mg/l	1200
TOC, mg/l	340