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Membrane fouling of a hybrid moving bed membrane bioreactor plant to treat real urban wastewater

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ABSTRACT

The influence of operative variables in the performance of an ultrafiltration membrane in a hybrid moving bed membrane bioreactor treating real urban wastewater was studied in relation to the fouling rate and the recovery of permeability with a multivariable statistical analysis. Twenty-one cycles of operation were studied in relation to the filling ratio, flux, temperature, biomass concentration in a pilot-scale experimental plant. The pilot plant consisted of three units of ZW-10 submerged membrane and 20, 35 and 50% of K1 of Anoxkaldnes were used as carrier. The statistical analysis has shown that the most influential variables in the performance of the membrane were temperature and flux. Transmembrane pressure ranged from 22 kPa to 68 kPa, increasing with the MLSS, BFSS and flux and decreasing with temperature. The presence of biofilm negatively affected the performance of the membrane in relation to the fouling rate; this varied between 0.26 and 1.22 kPa/day, and was found to increase when viscosity and BFSS increased and temperature decreased.

1. Introduction

Advanced technologies regarding wastewater treatment are necessary to preserve water quality and satisfy the limits imposed on the effluent from municipal wastewater treatment plants (WWTPs) by the Water Framework Directive [4]. Biological processes are a cost-effective and environmentally friendly alternative [25] that allow the complete treatment of the wastewater [5]. However, the efficiency of biological processes can be improved with the use of membranes. Membrane separation processes are widely used in water desalination, biochemical processing, industrial wastewater treatment, food and beverage production, and pharmaceutical applications [10]. Membrane bioreactors (MBR), which replace the settling tank with membrane filtration [11,35], represent an attractive treatment technology in wastewater management, since they produce a high quality effluent with not much surface demand [15]. Due to their unique advantages such as product quality, high efficiency, ease of operation and small footprint, membrane bioreactors have become state-of-the-art in wastewater treatment and are becoming increasingly popular [6,41].

In practical application processes, the efficiency of membrane filtration and separation is limited by concentration polarisation and membrane fouling problems [14]. Membrane fouling has been the main drawback to the wide application of MBR because it causes decreasing permeate flux or increasing transmembrane pressure [37], resulting in decreasing membrane performance and increasing frequent membrane cleaning and energy consumption [8,41]. The major factors affecting fouling, described by [9], are biochemical kinetic parameters, temperature, membrane characteristics, the characteristics of mixed liquor, operational style and reactor hydraulic conditions. The mixed liquor suspended solids concentration (MLSS) and flux of the membrane affect membrane fouling in MBR processes [29,30]. Therefore, membrane fouling mechanisms are very complicated due to the complex rheological and physiological characteristics of mixed liquors [2].

An alternative to managing this problem is the hybrid moving bed biofilm reactor (MBBR)–MBR. Using this technology, the biofilm system may reduce the concentration of suspended solids

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and improve the extent of membrane fouling [38], providing optional strategies for minimising the problem of fouling [12], in comparison with MBR. The hybrid MBBR technology has emerged as a compact treatment alternative to conventional activated sludge reactors for the treatment of municipal and industrial wastewater [27]. This system combines suspended biomass and biofilm processes inside the biological reactor for biofilm growth [26]. Therefore, they include positive aspects of the growth of suspended and attached biomass and aim to partially mitigate the fouling concerns in relation to MBR systems and the settleability issues regarding MBBR systems [18]. In contrast to most biofilm processes, the whole volume can be used for biomass growth [7]. Another important advantage of hybrid MBBR system is that the filling ratio of biofilm carriers in the reactor may be subject to preferences [33]. Martín-Pascual et al. [22] showed that the COD and BOD_5 removals in a hybrid MBBR-MBR working under a lower concentration of MLSS were similar to those obtained in an MBR working with high MLSS concentrations due to the presence of suspended and attached biomass.

The aim of the research was to study the influence of operative variables filling ratio, flux, dynamic viscosity, temperature and biofilm suspended solids concentration (BFSS) on the performance of an ultrafiltration membrane in a complex technology such as a hybrid moving bed membrane bioreactor to treat real urban wastewater throughout the fouling rate and the recovery of the permeability after the backwashing and chemical cleaning with a statistical multivariate analysis.

2. Material and methods

2.1. Experimental procedure

2.1.1. Description of the pilot-scale experimental plant

A pilot-scale experimental plant of hybrid MBBR-MBR was used in this research. The pilot plant was located in the WWTP Los Vados of Granada (Spain). The influent was taken from the outlet of the primary settler of the WWTP, so, the pilot plant was fed with real urban wastewater pretreated with a conventional physical pretreatment and primarily settled. As shown in Fig. 1, the experimental plant had two bioreactors: a bioreactor with an operating volume of 358 L and a tank with three submerged Zenon® hollow fibre ultrafiltration membrane units. In the first part, biodegradation took place and presented a 20, 35 and 50% filling ratio (rate between the apparent carrier volume and the operational volume of the bioreactor) of carriers. In the second part, solid separation was carried out and with an operating volume of 87 L.

The modules used were ZW-10, the configuration of which is outside/in hollow fibre with a nominal membrane surface area of $0.93\,m^2$, a nominal pore size of $0.04\,\mu m$ and an absolute pore size of $0.1\,\mu m$. The carriers used were K1, developed by AnoxKaldnes® AS (Norway). This carrier is made of high-density polyethylene and shaped into small cylinders with a cross inside the cylinder and "fins" on the outside; this provides a greater surface-to-volume ratio. Their density values range from 0.92 to $0.96\,g\,cm^{-3}$ and the specific biofilm surface area in bulk is $500\,m^2\,m^{-3}$; it has been recognised that the biofilm is negligible on the outer surface of K1 carriers [33].

In order to maintain the concentration of biomass in both reactors, a recycling pump with a constant flow of 90 L/h took the sludge from the membrane tank to the hybrid MBBR. In this way, the characteristics of the suspended biomass were similar and the Solids Retention Time (SRT) could be defined for the global system. The excess sludge was extracted under constant flow in each phase according to the SRT.

2.1.2. Operating conditions

During the study, the submerged membrane units were operated at a constant flux using a suction pump in each cycle, and varying the transmembrane pressures (TMP). The cyclic mode

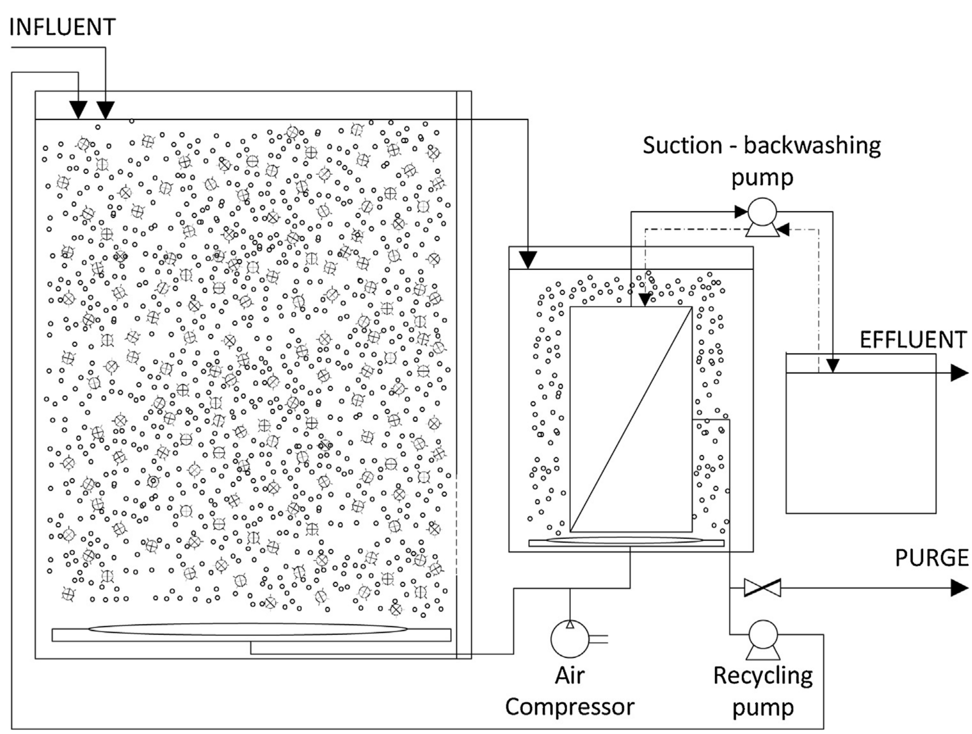

Fig. 1. Schematic diagram of the pilot plant of hybrid MBBR-MBR used with a cylindrical tank in which k1 of Anoxkaldness carriers were contained in a 20, 35 and 50% of filling ratio and a rectangular tank in which three units of ZW10 of Zenon were submerged. Dashed line represents the backwashing flux.