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Dead-end filtration of natural organic matter: experimental evidence of critical conditions

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Abstract

The development of membrane technology has reached a state whereby operational optimisation is becoming the major issue to both researchers and industrial operators. A key focus is towards sustainable operation where fouling is limited and cleaning is greatly reduced. The paper presents an example of such an approach for the filtration of natural organic matter (NOM) in a dead-end ultrafiltration cell. Sustainable operation has been assessed in relation to the application of a cessation period followed by a gentle rinse. The work demonstrates the existence of a critical filtered volume below which the mass accumulated at the membrane's surface is reversible and above which significant fouling occurs. Further, appropriate selection of operating conditions (filtered volume and applied pressure) makes it possible to avoid the formation of an irreversible fouling layer.

Keywords: Fouling; NOM; Critical flux; Critical filtered volume; Irreversibility

1. Introduction

Industrial use of membrane processes for physical separation has now become an established process option. Inherent to all membrane processes is a reduction in productivity due to the accumulation of material in and on the membrane's surface, normally termed "fouling". In the filtration of natural surface water, there is a wide variety of components (soluble organic matter, particles, colloids) leading to heterogeneity in terms of size and surface properties (charge, hydrophilic or hydrophobic interactions). Consequently, fouling can occur through a number of mechanisms:

- concentration polarization phenomena: during filtration, accumulated particles remaining in the dispersed phase at either the membrane/suspension or deposit/suspension interface provide a pressure in opposition to the separation force in terms of osmotic pressure. This

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resistance is reversible by simply decreasing the driving force.

- cake or gel formation: cohesive multilayer fouling can form when the concentration at the membrane reaches a critical point. The particles become interlinked in an irreversible deposit or gel presenting several degrees of compactness. This kind of fouling needs a back flush or a significant shear stress to be reversed.
- adsorption: physicochemical interactions between the various organic substances and the membrane can lead to irreversible fouling. This phenomenon is exacerbated by high local concentrations at the membrane's surface.
- internal fouling: particles can block internal pores due to differences in the shape of the foulant material or adsorption. This contribution of fouling is irreversible in regard to a decrease in the separation force and can be partly removed with a back flush.

Studies in the literature have shown fouling and its irreversibility to be a complex phenomenon which is dependent on the membrane [1], solution characteristics [2] and operating parameters [3]. Improvement in such separation processes requires rapid and straightforward identification of operating conditions that lead to a sustainable process.

A classic example of this is the concept of critical flux, which has been developed [4,5] to describe low fouling conditions in cross-flow filtration (when a steady state is reached). More recently the concept has been refined into three separate concepts described as critical, transitional and sustainable flux. In the current study the most appropriate refinement relates to sustainable flux which is defined as a flux policy in which fouling is minimised and maintained in a pseudo-steady state. The flux policy relates to whatever combination of flux rate, cross flow rate and cleaning regime is required to generate a stabilised operation. However defined, the parameter refers to the point prior to the onset of the irreversible multilayer fouling on the membrane's surface. For dead-end filtration, operating continually in a transient state, this description cannot be directly applied. Instead the concept of a critical accumulated mass is considered below where an irreversible layer deposition can be avoided [6].

The aim was to investigate the idea that it may be possible to avoid irreversible fouling formation in dead-end filtration, even if the suspension studied contains organic material. Experiments were performed by rinsing the membrane after filtration of different volumes in order to quantify variation of fouling reversibility with filtered volume. Effects of pressure and soaking on the fouling mechanisms were studied and analysed through the specific flux and the distribution in reversibility of fouling resistances.

2. Materials and methods

2.1. Feed suspensions

The current investigation was conducted on real raw water from a water treatment works in the north of England. The water is characterised as high DOC (9 mg L^{-1}), high UV absorption (42.5 m^{-1} at 254 nm) and low turbidity (2.3 NTU). Consequently, the main fouling mechanism was expected to be adsorption based. The water was stored at a constant temperature of +4°C and brought to room temperature before the experiment. The characteristics of the water were constant during the experiments.

2.2. Experimental device

The filtration experiments were performed with a bench-scale unit (Fig. 1) using ultrafiltration flat-sheet membranes provided by Aquasource (Toulouse, France) allowing an average removal of 18% of DOC. The rig was composed of a 0.2 L filtration cell (model KST 47, Advantec