Bioresource Technology 100 (2009) 6133–6136

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Short Communication

# Prediction of membrane fouling in MBR systems using empirically estimated specific cake resistance

S. Jamal Khan [a,*], C. Visvanathan [b], V. Jegatheesan [c]

[a] Institute of Environmental Science and Engineering, School of Civil and Environmental Engineering, National University of Sciences and Technology, Sector H-12, Islamabad, Pakistan
[b] Environmental Engineering and Management Program, School of Environment, Resources and Development, Asian Institute of Technology, Klong Luang, Pathumthani, Thailand
[c] School of Engineering, James Cook University, Townsville, Queensland, Australia

ARTICLE INFO

*Article history:*
Received 7 April 2009
Received in revised form 9 June 2009
Accepted 11 June 2009
Available online 10 July 2009

*Keywords:*
Membrane bioreactor
Membrane fouling
Specific cake resistance
Shear intensity
Cake filtration model

ABSTRACT

The focus of this study was to empirically estimate the specific cake resistance (SCR) by the variation in shear intensity ($G$) in four laboratory-scale MBRs. The control reactor ($MBR_0$) was operated with aeration only while other MBRs ($MBR_{150}$, $MBR_{300}$ and $MBR_{450}$) were operated with aeration and mechanical mixing intensities of 150, 300 and 450 rpm, respectively. It was found that the SCR was strongly correlated ($R^2 = 0.99$) with the fouling rates in the MBRs. Moreover, the contribution of cake resistance ($R_c$) to the total hydraulic resistance ($R_t$) was predominant compared to the irreversible fouling resistance ($R_f$). On this basis, the cake filtration model was selected as a predictive tool for membrane fouling. This model was modified by replacing the SCR with its empirical shear intensity relationship. The modified model can predict the fouling rate for a given shear intensity ($G$) within 80 and 250 $s^{-1}$ in a MBR system.

© 2009 Elsevier Ltd. All rights reserved.

## 1. Introduction

Membrane bioreactor (MBR) is a combination of biological degradation by activated sludge and direct solid–liquid separation by membrane filtration. In a MBR installation, separation of activated sludge and treated wastewater is achieved by filtration using microfiltration (MF) or ultrafiltration (UF) membrane technology. Compared with conventional wastewater treatment processes, MBRs offer several advantages including high biodegradation efficiency, excellent effluent quality, low sludge production and compactness (Le-Clech et al., 2006). As a result, MBR offers an attractive option for the treatment and reuse of industrial and municipal wastewaters. However, membrane fouling in MBR is considered as a major limitation to faster commercialization of MBR technology and is considered as the most serious problem affecting system performance. Thus, membrane fouling models that can accurately depict the propensity of fouling rates are valuable for the design and control of MBR systems. Fouling models investigated so far by researchers are theoretical, empirical or integrated models (Ng and Kim, 2007).

### 1.1. Theoretical model: resistance-in-series

The simplest theoretical model that describes the membrane fouling phenomena is the resistance-in-series model:

$$J = \frac{\Delta P}{\mu R_t} \tag{1}$$

$$R_t = R_m + R_c + R_f \tag{2}$$

where $R_t$ is the total hydraulic resistance, $R_c$ is the cake resistance caused by the cake layer deposited over the membrane surface and $R_f$ is the fouling resistance caused by adsorption of dissolved matter and/or colloidal pore blockage within the membrane.

According to cake filtration theory, the cake resistance is expressed as (Bowen and Jenner, 1995):

$$R_c = \frac{\alpha \cdot V \cdot C_b}{A_m} \tag{3}$$

where $\alpha$ is the specific cake resistance, $V$ is the total volume filtered, $C_b$ is the bulk concentration and $A_m$ is the membrane filtration area.

The combination of Eqs. (1) and (2) (excluding $R_m$ and $R_f$ fraction) and (3) with $J = A_m^{-1}\, dV/dt$ gives by integration the constant pressure filtration equation:

$$\frac{t}{V} = \frac{\mu \cdot \alpha \cdot C_b}{2A_m^2 \Delta P} V \tag{4}$$

Eq. (4) yields a straight line on plotting experimental data of $t/V$ versus $V$ which allows determination of specific cake resistance ($\alpha$). $\alpha$ can be approximately related to the properties for spherical particles by Carmen–Kozeny relationship:

$$\alpha = \frac{180(1-\varepsilon_c)}{\rho \cdot d_p^2 \cdot \varepsilon_c^3} \tag{5}$$

* Corresponding author. Tel.: +92 51 90854662.
*E-mail address:* jamal@iese.edu.pk (S.J. Khan).

0960-8524/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biortech.2009.06.037