Journal of Membrane Science 325 (2008) 311–318

Contents lists available at ScienceDirect

Journal of Membrane Science

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

The impact of in-line coagulant addition on fouling potential of secondary effluent at a pilot-scale immersed ultrafiltration plant

Joel Citulski*, Khosrow Farahbakhsh, Fraser Kent, Hongde Zhou

School of Engineering, Guelph, ON N1G 2W1, Canada

ARTICLE INFO

Article history:
Received 23 April 2008
Received in revised form 23 July 2008
Accepted 24 July 2008
Available online 9 August 2008

Keywords:
In-line coagulation
Tertiary treatment
Immersed UF
Fouling
Colloids

ABSTRACT

The impact of in-line coagulation pre-treatment of secondary effluent on the operation of an immersed hollow-fibre ultrafiltration membrane pilot was evaluated as part of a larger study on optimising phosphorus removal. The efficacy of alum and ferric chloride was investigated, with an emphasis on alum use. Both coagulants were found to shift the particle-size distribution of organic matter in the feed towards larger fractions, with a notable reduction in colloidal matter. This was reflected in a reduction of both average daily transmembrane pressure increases, as well as a reduction of transmembrane pressure increases within backpulse intervals. Fouling reduction was observed with both lower and higher membrane packing density modules (membrane surface areas of 55.7 and 62.7 m^2/module). The results of one-way analysis of variance (ANOVA) testing indicate that for this pilot system, chemical pre-treatment and solids concentrations in the feed water played a statistically significant role in determining transmembrane pressure variations. Membrane packing density and membrane production method did not exhibit a statistically significant effect on transmembrane pressure under the conditions of this study.

1. Introduction

Immersed hollow-fibre ultrafiltration membranes have become an increasingly important component of the tertiary treatment process at municipal wastewater treatment plants [1,2]. Minimisation of membrane fouling is critical to the successful long-term operation of membrane treatment systems, as fouling reduces both membrane lifespan and treated water production, thus increasing the costs of membrane treatment [3]. Total suspended solids levels have been suggested as a useful (and relatively easily measured) predictor of membrane fouling in tertiary UF treatment [4], a finding that has been validated during research leading to the present study. However, the most severe fouling of UF membranes in tertiary treatment settings appears to result from colloidal matter and dissolved organic substances [5–7].

Identifying the constituents of colloidal matter and dissolved organic substances that most strongly contribute to fouling is a matter of ongoing research. Lee et al. [7] identified colloids in the size range of 0.2–1.2 μm as being the most significant cause of fouling, based on experiments in which secondary effluent was pre-filtered before being fed to bench-scale UF modules. Howe and Clark [8] found that particles greater than 0.45 μm in size had little effect in membrane fouling, based on studies in which high-turbidity surface water was fractionated through membranes with varying molecular weight cut-offs and the resulting filtrate used as feed for bench-scale flat-sheet UF membranes. Small colloids in the size range of 0.003–0.02 μm were considered the predominant cause of flux decline. An early study by Lahoussine-Turcaud et al. [9] using stock solutions of humic acid, tannic acid and kaolin clay as feed sources for bench-scale immersed hollow-fibre UF membranes concluded that particle sizes of approximately 0.2 μm led to the highest flux declines. Colloidal organic matter has also been observed to act as a determinant of UF fouling in membrane bioreactors [10–11].

The use of coagulants as a pre-treatment in advance of UF has been identified as mitigating the fouling potential of secondary effluent [7,12]. Studies suggest that this effect is due to the agglomeration of colloidal and dissolved matter into particles that are too large to cause pore narrowing and pore plugging [6,13]. As part of a broader study investigating the ability of in-line coagulant addition to remove phosphorus from secondary effluent during the pilot-scale tertiary treatment of wastewater using hollow-fibre immersed UF membranes, the present study also considered the

* Corresponding author. Tel.: +1 519 824 4120x52231; fax: +1 519 836 0227.
E-mail addresses: jcitulsk@uoguelph.ca (J. Citulski), khosrowf@uoguelph.ca (K. Farahbakhsh), fkent@uoguelph.ca (F. Kent), hzhou@uoguelph.ca (H. Zhou).

0376-7388/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.memsci.2008.07.053

Table 1
Membrane characteristics

Parameter	Specification
Module type	ZeeWeed® 1000 v.3
Outside fibre diameter	0.75 mm
Inside fibre diameter	0.35 mm
Nominal pore size	0.02 μm
Absolute pore size	0.1 μm
Surface area	
Until 08/02/2007	55.7 m^2/module
09/02/2007–14/06/2007	62.7 m^2/module
15/06/2007–present	55.7 m^2/module
Fibre orientation	Horizontal
Flow direction	Outside–in
Chemistry	PVDF (oxidant tolerant)
Hydrophobicity	Hydrophilic

Table 2
Feed water quality parameters

Parameter	*n*	Maximum	Minimum	Average ± S.D.
pH	135	8.20	7.15	7.78 ± 0.16
Turbidity (NTU)	233	35.8	0.9	4.37 ± 3.69
TSS (mg/L)	123	31.2	1.40	10.07 ± 6.55
Temperature (°C)	233	21.9	8.1	15.0 ± 4.8
$UVA_{254\,nm}$ (cm^{-1})	104	0.157	0.103	0.133 ± 0.014
TOC (mg/L)	131	24.35	6.001	13.98 ± 4.40
COD (mg/L)	109	63.05	8.94	28.88 ± 10.69

effects of coagulant addition on membrane fouling. The impact of coagulant addition was evaluated by examining both long-term fouling rates and the increases in operating transmembrane pressure between backpulse intervals. The impact of coagulant treatment on modifying the particle-size distribution in the secondary effluent was monitored by fractionating the total organic carbon (TOC) content into three fractions: particles with a size greater than 1.5 μm, particles between 0.45 and 1.5 μm in size, and particles between 0.45 and 0.1 μm (the absolute pore size of the UF membrane).

2. Materials and methods

2.1. Pilot plant

The immersed hollow-fibre ultrafiltration pilot used in this study was installed at the City of Guelph Wastewater Treatment Plant (WWTP), in Guelph, ON, Canada. The pilot was designed to hold three modules of ZeeWeed 1000® membranes (GE Water and Process Technologies). Membrane characteristics are presented in Table 1.

As shown in Table 1, three different types of membranes were used during this study. The first two sets of modules had PVDF membranes manufactured using an identical process, but differed in terms of membrane packing density (55.7 m^2/module versus 62.7 m^2/module). The third set of modules had the original packing density of 55.7 m^2/module and were made of PVDF, but were manufactured using an updated proprietary process.

The City of Guelph WWTP's treatment train consists of preliminary screening and grit settling, followed by a two-stage conventional activated sludge process. Ferrous chloride is added at the headwork and primary clarifiers for phosphorus removal. Tertiary treatment consists of rotating biological contactors for biological nitrification followed by rapid sand filters. Feed for the pilot was pumped via a submersible pump from a collection well that combined the secondary effluent from three of the WWTP's four secondary clarifiers. A schematic of the pilot is shown in Fig. 1. Note that because part of the study involved the re-dosing of phosphate (removed earlier in the conventional wastewater treatment process) into the pilot's feed to assess phosphorus removal capabilities, the dosing system was equipped for addition of both sodium triphosphate and liquid coagulants (alum and ferric chloride).

Selected water quality parameters of the secondary effluent feed are shown in Table 2.

Of note is the fact that the maximum concentration of total suspended solids (TSS) measured in the feed based on grab-sampling (31.2 mg/L) may have actually been significantly higher. TSS levels for each of the three secondary clarifiers contributing to the pilot's feed stream (obtained from the Guelph WWTP's analytical laboratory), combined with clarifier flow data, indicate that TSS in the combined effluent feed rose as high as 133 mg/L. A summary of coagulant treatment intervals and maintenance events at the pilot is presented in Table 3.

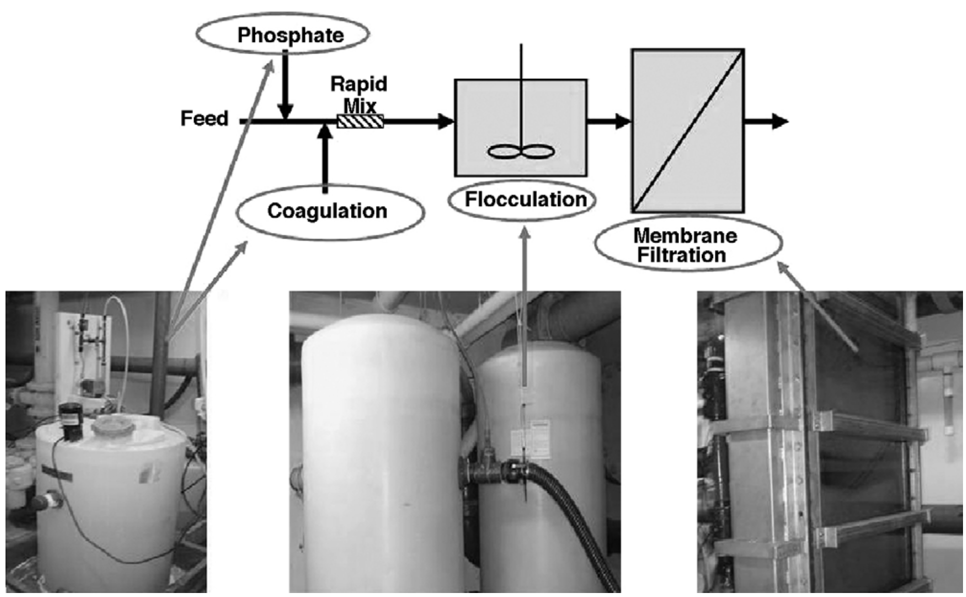

Fig. 1. Guelph WWTP tertiary pilot setup.