



## Pre-treatment of surface waters for ceramic microfiltration



D. Metcalfe<sup>a</sup>, P. Jarvis<sup>b</sup>, C. Rockey<sup>a</sup>, S. Judd<sup>b,c,\*</sup>

<sup>a</sup>South West Water, Exeter, UK

<sup>b</sup>Cranfield University, Cranfield, Beds, UK

<sup>c</sup>Qatar University, Doha, Qatar

### ARTICLE INFO

#### Article history:

Received 22 December 2015

Received in revised form 23 February 2016

Accepted 25 February 2016

Available online 26 February 2016

#### Keywords:

Ceramic membrane  
Pretreatment  
Ion exchange  
Coagulation  
Organic fouling

### ABSTRACT

The influence of pre-treatment on the suppression of irreversible (IR) fouling of ceramic membranes challenged with three UK surface waters has been studied at pilot scale. An initial scoping study compared the efficacy of suspended ion exchange (SIX) and clarification (coagulation followed by sludge blanket clarification) individually and in combination. Direct membrane filtration following in-line coagulation (ILCA) was also investigated with and without SIX. The impact on the various organic fractions, specifically high molecular weight (HMW) biopolymers (BPs) and humic substances (HSs), and lower molecular weight (LMW) building blocks (BBs) and neutrals, was studied using liquid chromatography-organic carbon detection (LC-OCD).

Results revealed SIX and coagulation to preferentially remove the LMW and HMW organic fractions respectively. Residual HMW organic matter (primarily BPs) following SIX pre-treatment were retained by the membrane which led to rapid irreversible fouling. Coagulation pre-treatment provided stable membrane operation and the residual LMW organics were not significantly retained by the membrane. Combining clarification and SIX resulted in significantly increased removal of organics and lower membrane fouling rates. Tests performed using SIX and ILCA revealed high dissolved organic carbon (DOC) removal compared to SIX with clarification. However, unlike the case for clarification with SIX, the addition of SIX to optimised ILCA dosing offered no additional suppression of membrane fouling compared to ILCA alone. Optimised ILCA pretreatment led to very low IR fouling rates of <0.3 kPa/day trans-membrane pressure, despite highly challenging operating conditions of elevated fluxes (185 L m<sup>-2</sup> h<sup>-1</sup>) and highly variable feedwater dissolved organic carbon concentrations.

© 2016 Elsevier B.V. All rights reserved.

### 1. Introduction

Historically, the conventional processes of coagulation, clarification and granular media filtration have been used for removing suspended material and natural organic matter (NOM) from surface water prior to disinfection [1]. Membrane filtration offers some key advantages over such processes, including higher

removal efficiency, compactness, robustness against fluctuating feed water quality, and the provision of an absolute barrier against suspended particles and pathogens such as *Cryptosporidium* [11,27]. Membranes have thus been increasingly applied for water treatment [12], with polymeric materials being most commonly used.

Recently there has been increased interest in ceramic membranes for potable and industrial water treatment applications due to their greater operational life, solids loading capacity, sustainable flux rates (from reduced organic fouling), mechanical robustness and resistance to aggressive cleaning protocols [10,18]. These and other technological benefits have meant that the higher capital costs associated with ceramic membranes can be significantly offset by lower operating costs over the life of the installation, making ceramic membranes potentially economically competitive [6,21,25].

Membrane fouling nonetheless remains a major obstacle to the application of membranes per se. Much research has been focussed

**Abbreviations:** BBs, building blocks; BPs, biopolymers; BW, backwash; CEB, chemically enhanced backwash; CIP, cleaning in place; CMF, ceramic microfiltration; DOC, dissolved organic carbon; HMW, high molecular weight; HSs, humic substances; IEX, ion exchange; ILCA, inline coagulation; IR, irreversible; LC-OCD, liquid chromatography-organic carbon detection; LORIV, lowland river (River Tamar); LMW, low molecular weight; LMW-N, low molecular weight-neutrals; NOM, natural organic matter; NTU, Nephelometric turbidity unit; PACl, poly-aluminium chloride; SIX, suspended ion exchange; TMP, trans-membrane pressure; UPRES, upland reservoir (Burrator Reservoir); UPRIV, upland river (River Tavy); UVT, filtered UV transmittance at 254 nm; WTWs, water treatment works.

\* Corresponding author at: Cranfield University, Cranfield, Beds, UK.

E-mail address: [s.j.judd@cranfield.ac.uk](mailto:s.j.judd@cranfield.ac.uk) (S. Judd).

on understanding fouling mechanisms and identifying pretreatment capable of removing highly-fouling compounds [11]. Such research has generally revealed that the high molecular weight (HMW) biopolymer (BP) fraction of NOM is primarily responsible for irreversible (IR) membrane fouling, demanding intensive chemical cleaning in place [4,26,16]. Pretreatment methods which substantially remove the BP fraction have been shown to provide stable membrane operation, with coagulation being the most consistently successful method [3,12,14]. Coagulation preferentially flocculates the HMW organics, including BPs, the resulting solids then being removed either by clarification (e.g. sludge blanket clarification or dissolved air flotation) or, where “in-line” coagulation with direct filtration is used, by the backwash cycle of the membrane process.

Adsorption processes (anion exchange and activated carbon) have been shown to improve treated water quality through the removal of low molecular weight (LMW) organics but, since they remove only small amounts of the HMW fraction, in most cases fouling reduction appears to be minimal [14,3,4,12]. Against this, some studies have revealed LMW organics to cause or contribute to fouling through synergistic action with the higher MW fraction [8,24,17]. Such differences in findings highlight the complexity of interactions between the organic constituents and the membrane material and fouling layer.

Since coagulation and adsorption, and specifically ion exchange processes (IEX), have been shown to preferentially remove the high and low MW fractions of the NOM respectively, it may be surmised that their use in combination may both improve permeate water quality and suppress membrane fouling. However, previous studies of the use of combined IEX and coagulation upstream of membrane filtration have not unequivocally demonstrated membrane fouling benefits: reported fouling rates have been similar to those possible with coagulation alone [14,4].

The current study aimed to evaluate suppression of irreversible fouling of ceramic membranes associated with pretreatment by suspended ion exchange (SIX), coagulation or a combination of both. The analysis proceeded through quantification of the organic fractions removed by both pretreatment and the membrane itself, and examined the resulting impact on membrane fouling. Experiments were conducted for three UK surface waters at large pilot scale over a 26-month period under conditions appropriate for potable water production. The irreversible fouling rate was assessed from trans-membrane pressure (TMP) transients generated under operating conditions (including physical and chemically enhanced backwashing) pertaining to those applied at full-scale.

## 2. Materials and methods

### 2.1. Raw waters

Three raw waters were tested, either individually or as a blend:

- An upland reservoir (UPRES) of low turbidity and low-to-moderate dissolved organic carbon (DOC) (Burrator Reservoir).
- A soft, upland river (UPRIV), prone to rapid changes in quality following rain, of low-to-high DOC and low-to-moderate turbidity (River Tavy).
- A lowland river (LORIV) prone to rapid changes in quality following rain of low-to-high DOC and turbidity (River Tamar).

### 2.2. Pilot plant

The 150 m<sup>3</sup>/day pilot plant (Fig. 1) comprised the SIX<sup>®</sup> and ceramic membrane filtration (CMF) (CeraMac<sup>®</sup>) processes and subse-

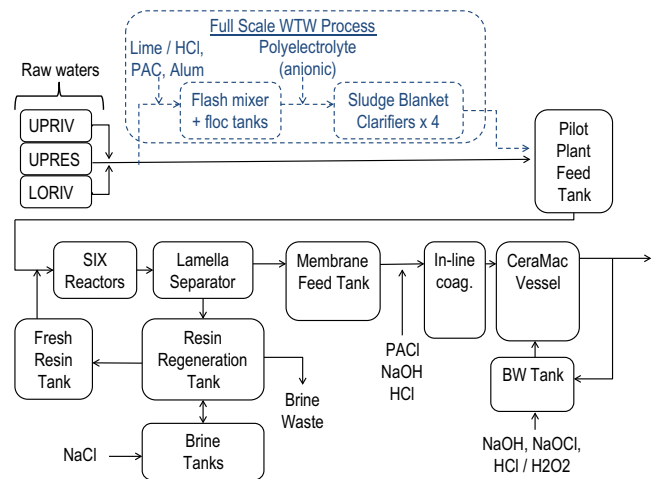


Fig. 1. Process flow diagram.

quently the SIX<sup>®</sup>, in-line coagulation (ILCA<sup>®</sup>) and CMF (PWN Technologies, Netherlands) as described elsewhere [7,20]:

- SIX<sup>®</sup>: an acrylic quaternary amine, gel-type strongly basic anion exchange resin in the chloride form was used throughout the trial (Lewatit S5128, Lanxess, Germany). The resin was generally dosed at 18 mL/L with a contact time of 30 min, with dosing conditions informed by preliminary bench-scale tests. Tests were also performed with lower or zero resin doses (i.e. with ILCA<sup>®</sup> only) as appropriate. The resin was in continuous use over the 2 years of the trial.
- A Lamella separator was used for separating the resin from the treated flow and the resin regenerated with 30 g/L NaCl. SIX-treated water samples were collected directly after resin separation.
- ILCA<sup>®</sup> using polyaluminium chloride (WAC<sup>®</sup>, Water Treatment Solutions, UK, 0.53–4.23 mg/L as Al) was used alone or following SIX pretreatment. Water was pH-corrected with NaOH or HCl (Brenntag, U.K), injected with coagulant, and mixed by a static mixer and flocculated for 2.4–3.9 min prior to CMF (direct filtration). The coagulation pH was circa 6.4 for all tests.
- CMF was carried out using a vertically mounted 25 m<sup>2</sup> ceramic membrane element (Metawater, Japan, nominal pore size 0.1 mm) operating by dead end filtration.

### 2.3. Full scale WTW process

The water treatment works (Crownhill WTW, South West Water (SWW), Plymouth, U.K) treated water using optimised coagulation with aluminium sulphate dosed at 3.39–6.36 mg/L as Al (Kemira, U.K) and Magnafloc LT25 (BASF, U.K) anionic polyelectrolyte at 0.1–0.2 mg/L. Powdered activated carbon (PAC, Aquasorb BP2, Jacobi, U.K) was dosed at 2–3 mg/L prior to coagulation. The WTW coagulant dose was optimised through jar testing and works operation. Clarified water following flash mixing, flocculation and solids–liquid separation (by sludge blanket clarification) was supplied to the pilot plant for some of the tests.

### 2.4. Pretreatment

The pilot plant was fed with either raw or, during the clarification or clarification + SIX campaigns, clarified water (Fig. 1).

Tested pretreatment options for CMF comprised:

Download English Version:

<https://daneshyari.com/en/article/640091>

Download Persian Version:

<https://daneshyari.com/article/640091>

[Daneshyari.com](https://daneshyari.com)