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Effect of ozone on biopolymers in biofiltration and ultrafiltration processes

Barbara Siembida-Lösch [a,*], William B. Anderson [a], Yulang (Michael) Wang [a], Jane Bonsteel [b], Peter M. Huck [a]

[a] NSERC Chair in Water Treatment, University of Waterloo, 200 University Ave West Waterloo, ON N2L 3G1, Canada

[b] Water Division, Public Works Peel Region, 920 East Avenue, Mississauga L5E 1W6, Canada

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ABSTRACT

The focus of this full-scale study was to determine the effect of ozone on biopolymer concentrations in biofiltration and ultrafiltration (UF) processes treating surface water from Lake Ontario. Ozonation was out of service for maintenance for 9 months, hence, it was possible to investigate ozone's action on biologically active carbon contactors (BACCs) and UF, in terms of biopolymer removal. Given the importance of biopolymers for fouling, this fraction was quantified using a chromatographic technique. Ozone pre-treatment was observed to positively impact the active biomass in biofilters. However, since an increase of the active biomass did not result in higher biopolymer removal, active biomass concentration cannot be a surrogate for biofiltration performance. It was evident that increasing empty bed contact time (EBCT) from 4 to 19 min only had a positive effect on biopolymer removal through BACCs when ozone was out of service. However, as a mass balance experiment showed, ozone-free operation resulted in higher deposition of biopolymers on a UF membrane and slight deterioration in its performance.

1. Introduction

Components of natural organic matter (NOM) have been found to be responsible for fouling of low-pressure membranes (LPMs) (e.g. Hallé et al., 2009; Tian et al., 2013), leading to higher energy consumption, more frequent chemical and/or heated cleaning, shorter membrane life, and longer downtimes.

Among the microbially-derived dissolved NOM components, biopolymers, which are comprised of polysaccharides, proteins, or protein-like substances, have been recently identified as key foulants of LPMs, affecting their performance (Amy, 2008; Hallé et al., 2009; Peter-Varbanets et al., 2011). Huck et al. (2013) summarized the fouling components of NOM (i.e. organic material with high and low molecular weight (LMW) and high hydrophobic content, hydrophilic material, colloidal material, etc.) from previous studies, conducted prior to the availability of Liquid Chromatograph-Organic Carbon Detection (LC-OCD) (Huber et al., 2011). This method permits quantification of hydrophobic and hydrophilic dissolved organic carbon (DOC) fractions at the relatively low concentrations typically found in surface waters. The latter can be further quantified

* Corresponding author.
E-mail address: barbara.siembida@gmx.de (B. Siembida-Lösch).
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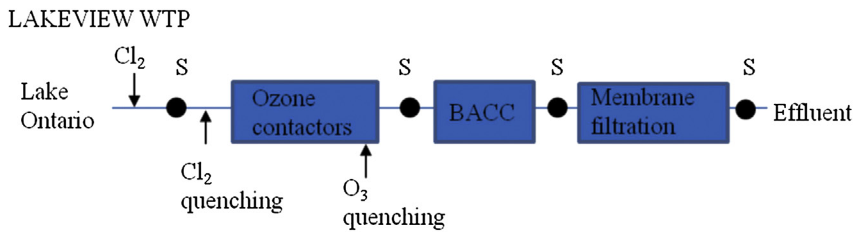

Fig. 1 – Lakeview WTP advanced treatment train flowsheet. BACC-biologically active carbon contactors (S – sampling point).

as sub-fractions defined as biopolymers, humic substances, building blocks, and LMW acids and neutrals. The studies referenced above have demonstrated a relationship between biopolymer concentration and LPM hydraulically reversible and irreversible fouling. This is consistent with results of some other authors (Zheng and Croue, 2012; Wei and Amy, 2012; Tian et al., 2013), who also reported that membrane filtration of treated domestic wastewater led to fouling due to the accumulation of biopolymers on the membrane surface and/or in the pores. Therefore, given the importance of biopolymers for LPM fouling, their quantification and control is crucial for water treatment facilities using membranes.

Fouling control may be achieved by pre-treating LPM feedwater, which has been widely employed at full-scale to maximize efficiency, ensure integrity, and reduce costs. Some high-quality raw waters can be fed to an LPM without pre-treatment, as in the case of the Lorne Park Drinking Water Ultrafiltration Plant (Mississauga, Ontario, Canada), which was commissioned in 2011 (Siembida-Lösch et al., 2014). Whereas coagulation/flocculation, often with sedimentation, and sometimes oxidation are typical pre-treatment processes employed at full-scale plants treating surface water using granular media filtration, the most commonly utilized chemical pre-treatment for the removal of turbidity and NOM for LPMs is coagulation alone.

Coagulant-free biological filtration (biofiltration) as pre-treatment for LPMs has been demonstrated to effectively remove high molecular weight biopolymers associated with membrane fouling in surface water filtration (Hallé et al., 2009; Peldszus et al., 2012). Ozonation too seems to be a promising pre-oxidant for reducing organic fouling in LPMs (e.g. Huang et al., 2009). Pre-ozonation is often used in combination with biofiltration to remove easily biodegradable ozonation by-products (Huck, 1990; Melin and Ødegaard, 2000). Ozone, being a strong oxidant, can increase the biodegradability of NOM by changing its character (Yavich et al., 2004; Treguer et al., 2010), and as such it potentially would be feasible to integrate ozonation and biofiltration as a membrane pre-treatment. The combination of ozonation and biofiltration, however, has not been fully investigated and understood as LPM pre-treatment. The authors are aware of at least two full-scale examples where ozonation followed by biological activated carbon (BAC) filtration is being used prior to LPMs. The Les Gonelles Water Treatment Plant (WTP) in Vevey, Switzerland (Membratec, 2013) is one and the Lakeview WTP in the Region of Peel, Ontario, Canada (Farr and Stampone, 2007) is the second. The Lakeview WTP is the subject of this paper. When the plant was designed the combined ozonation/biofiltration processes were not specifically intended to reduce biopolymers, as the importance of the biopolymer fraction for membrane fouling had not yet been identified.

To the best of our knowledge, no published studies have aimed to investigate the effect of ozone on biopolymers in biofiltration and ultrafiltration full-scale processes. This work was thus conducted to evaluate combined ozonation/biofiltration as a pre-treatment for UF membranes with regard to biopolymer removal, and specifically to investigate 1) the effect of ozone on various DOC fractions; 2) biopolymer removal through biofiltration when ozone was on and off; 3) the effect of empty bed contact time (EBCT) and the active biomass concentration on biopolymer removal through BAC filtration when ozone was on and off; 4) the effect of ozone on protein and polysaccharide removal through BAC filtration, and finally 5) the effect of ozone on biopolymer retention/deposition by UF membranes and their performance.

Table 1 – Raw water quality parameters for the period between June 2011 and December 2013.

Parameter	Unit	Average	Min	Max	Number of samples
Temperature	°C	11.4	2.8	22.5	69
pH	–	7.8	7.1	8.7	69
Conductivity	μS/cm	303	220	361	65
Turbidity	NTU	0.47	0.22	1.64	69
$TOC_{(wet\ oxidation)}$	mg C/L	2.4	1.8	2.9	64
$DOC_{(wet\ oxidation)}$	mg C/L	2.2	1.7	3.0	63
$DOC_{(photochemical)}$	mg C/L	2.2	1.7	2.7	68
Biopolymers	μg C/L	300	164	448	69
SUVA	L/(mg C·m)	0.9	0.5	1.6	61