Desalination and Water Treatment
www.deswater.com

doi: 10.1080/19443994.2013.796731

51 (2013) 6420–6422
September

Taylor & Francis
Taylor & Francis Group

Reducing anionic and hydrophobic biofoulants with nonwoven filter media having high flux rate and low pressure drop

Heather Mowers*, Rodney Komlenic

Disruptor® Technology, Ahlstrom Advanced Filtration, 122 W Butler Street, Mount Holly Springs, PA 17065, USA
Tel. +1 717 486 6421; Fax: +1 717 486 6413; email: heather.mowers@ahlstrom.com

Received 14 February 2013; Accepted 15 April 2013

ABSTRACT

Biofouling of membranes is well known to be caused by submicron or molecular weight contaminants, that include organic acids and transparent exopolymer particles (TEP). Organic foulants significantly impede operation of many membrane systems in many ways, productivity downtime for cleaning, productivity loss from decreased permeability, and higher energy demand required to overcome decreased permeability and the use of chemicals that can damage both the membranes and the environment. Design of the filtration system can vary greatly based on the make-up of the contaminant load, water type, and the volume to be processed. This paper examines several different studies to show the benefits of using Disruptor® as a prefilter to minimize biofouling by removing specific organic compounds which are known to be linked to initial membrane biofouling. It also explores additional removal mechanisms that separate this technology from other commercially available electro-adsorptive filters.

Keywords: Ahlstrom Disuptor®; TEP; Electrostatic interactions; Hydrophobic interactions

Organic acids, transparent exopolymer particles (TEP), and other organic materials are present nearly in all water systems. These materials have been identified by many researchers as being ultimately responsible for the biofouling of membranes [1]. There are many common pretreatment options available to mitigate membrane fouling. These include; sedimentation, coagulation, and more recently the use of microfiltration or ultrafiltration (MF/UF) membranes. Sedimentation and coagulation are primary techniques used for many years to remove bulk particulate and organic contaminants through mechanical filtration and chemical treatment. Examples of these bulk removal systems would be centrifuges, depth media beds, filter cartridges, and polymeric membranes. MF/UF filtration, although effective in reducing a wide range of bulk contaminants, has a long service life. They have a high capital cost and typically operate at higher pressure which equates to high energy cost. MF/UF systems typically reduce but do not eliminate constituents of the foulants that have been shown to cause primary membrane fouling.

---

*Corresponding author.

Presented at the Workshop on Membrane Fouling and Monitoring, 21–22 September 2012, Balliol College, University of Oxford, UK

Biofoulants have been found to be efficiently removed using electroadsorptive filter media [1]. Electroadsorptive filter media can use electrostatic interactions produced through chemical modification to the surface of the material and/or through hydrophobic interactions between the contaminant and the media such as, nitrocellulose membranes or powdered activated carbon. A recent improvement in electroadsorptive technology has been the development of a high surface area microglass media using the charge potential generated by nanofibers of the mineral pseudoboehmite.

Electroadsorptive filters use cationic/anionic charge interactions as the primary removal mechanism of biofoulants. Most solutes carry a net negative charge, while the filter media carries a net positive charge. This leads to an enhanced removal of fouling constituents which are not retained by conventional mechanical filters. Materials such as TEP, which are electronegative, long-chain polysaccharides [2], are efficiently removed by electropositive filters. TEP appear as long sticky chains or agglomerates covering a wide size range [3,4]. These chains will shear when passing through hollow fiber membranes and can be further reduced in size through chemical shock treatment, allowing them to reach the membrane surface where they deposit as a primary foulant. Electroadsorptive filters also enhance removal of other organic fouling constituents that were not retained by conventional mechanical filters such as virus, bacteria, and cell debris including, DNA and RNA.

Viruses have different isoelectric points due to variations of the amino acid groups on their protein capsids, but they are typically electronegative above a pH of 3.5 [5]. Their anionic charge makes them available for removal through electroadsorption or electrostatic forces. Additionally, virus and organic acids are hydrophobic making them available for removal through like–like hydrophobic interactions that play a lesser, but still critical role to electrostatic interactions in the removal of contaminants.

Naturally occurring organic acids are well known to cause significant degradation in virus log reduction value (LRV) when using media having either electrical charge or that use hydrophobic interactions as the primary removal mechanism. When using filters with an anionic charge which is imparted through the use of a surface chemical treatment, the competition between organic acid and virus for the cationic charged surface area increases as a function of the amount of humic acid filtered.

Ahlstrom Filtration introduced a new type of filter media, Disruptor® that is thought to remove submicron contaminants through a naturally occurring cationic charge potential. This electrical potential is generated by the crystal structure of nanofibers of the mineral pseudoboehmite (AlOOH). The filter media is a wet-laid nonwoven that can be pleated into a filter design. It has a greater than 50 mv streaming zeta potential and removes small materials like organic and microbial macromolecules which are not captured by conventional filters and has a mean pore size smaller than 2 μ. The cartridge pressure drop is typically <0.1 bar.

Previous work [1] published recently examined nanoparticle removal from West Basin MF backwash water. The MF backwash water was filtered with Disruptor® and compared to unfiltered MF backwash water. The water contained both organic, particulate, and nanoparticulate materials of which about 5×10^8 particles/ml had a diameter of less than 500 nm. The Disruptor® filtered water reduced the nanoparticles from 80% upto 1×10^8 particles/ml. Reducing the nanoparticles to this extent also enabled the MF membrane using the Disruptor® filtered backwash water, to have an extended run time and less clean in place cycles because the fouling of the interior of the hollow fiber MF membrane was greatly slowed.

Having demonstrated the ability to reduce inorganic nanoparticles better than a MF membrane and producing a significant, measureable increase in time between CIP cycles, it was decided to further investigate the removal mechanisms of the adsorptive media.

As discussed earlier, the media's compositional chemistry and crystal structure of pseudoboehmite (AlOOH), are responsible for the electrokinetic positive charge potential. It is known that hydrophobic interactions between nitrocellulose membranes and virus cause the virus to be retained by the membrane [6]. Because the media has been found sometimes also to remove the cationic compounds and particulates an investigation that was carried out to determine if hydrophobic interactions could also be related to the removal of virus; one of the potential biofouling agents.

BCS Laboratories in Gainesville Florida, a NELAC accredited laboratory, was contracted to determine if Disruptor® also utilized hydrophobic interactions like nitrocellulose membranes to remove contaminants. Evaluations using 25 mm discs, a 10^4/ml concentration of virus, and 60 ml volumes were performed using three challenge solutions, each containing MS2 virus, and each being formulated to block a specific type of removal mechanism:

- A mixture containing 0.5 M magnesium chloride and MS2 to block electroadsorptive interactions.
- A mixture containing 4.0 M urea and MS2 to block hydrophobic interactions.

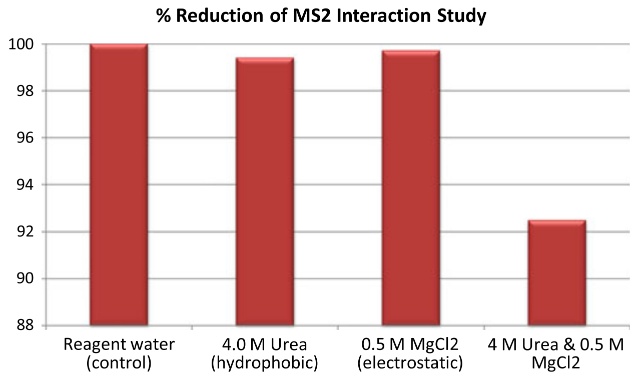

Fig. 1. Percent reduction of virus when electrostatic, hydrophobic, or both interactions are blocked.

- A mixture of both 0.5 M magnesium chloride and 4.0 M urea, and MS2 was used to block both electroadsorptive and hydrophobic interactions.

Test data indicates that Disruptor® removes virus through both electroadsorption and hydrophobic interactions. This was demonstrated by the fact, that when either magnesium chloride or urea was added, the other interaction compensated to remove the virus. When both solutions were mixed together blocking both removal mechanisms, virus removal dropped slightly but removal was still above 92% (Fig. 1). This may indicate that there are still other removal mechanisms like van der Waals forces in place to aid with removal.

In Lukasik's previous studies [6], he found that the concentration of magnesium chloride was sufficient enough to block electrostatic charges of positively charged competitor filters and urea was sufficient to block the hydrophobic removal mechanisms in nitrocellulose membranes. Based on the data, both hydrophobic and strong electrostatic interactions are believed to be responsible for virus adsorption in the filter media; something that is different when compared to the other electrostatic filters' in Lukasik's previous studies.

The Disruptor® filtration technology is unique in the way it combines the properties of a nonwoven, depth filter with the both electroadsorptive and hydrophobic interactions to remove biofoulants. Electroadsorptive capability is imparted to the media by the boehmite crystal structure while hydrophobic interactions are present from the glass fibers and carbon (which is available in certain grades of Disruptor®). Bales [7] found that hydrophobic interactions were the orders of magnitude which are more important in the attachment of MS2 to solids than electrostatic interactions. Shields [8] confirmed this and found that MS2 had the strongest hydrophobic and weakest electrostatic interactions of a series of different virus they compared. It can be considered that other biofouling agents could be removed to varying degrees by these interactions. Further study would be necessary to validate this hypothesis. A media exhibiting both electroadsorpitve and hydrophobic removal mechanisms should be considered as highly advantageous to many filtration applications where reduction of the contaminants responsible for primary and secondary membrane fouling is required.

References

[1] R. Komlenic, T. Berman, J.A. Brant, B. Dorr, I. El-Azizi, H. Mowers, Removal of polysaccharide foulants from reverse osmosis feedwater using electroadsorptive cartridge filters, Desalin. Water Treat. 51(4–6) (2013) 1050–1056.

[2] P. Verdugo, A.L. Alldredge, F. Azam, D.L. Kirchman, U. Passow, P.H. Santschi, The oceanic gel phase: A bridge in the DOM-POM continuum, Mar. Chem. 92 (2004) 67–85.

[3] L.O. Villacorte, M.D. Kennedy, G.L. Amy, J.C. Schippers, The fate of transparent exopolymer particles (TEP) in integrated membrane systems: Removal through pre-treatment processes and deposition on reverse osmosis membranes, Water Res. 43 (2009) 5039–5052.

[4] L.O. Villacorte, R. Schurer, M.D. Kennedy, G.L. Amy, J.C. Schippers, The fate of transparent xopolymer particles (TEP) in seawater UF-RO system: A pilot plant study in Zeeland, The Netherlands, Desalin. Water Treat. 13 (2009) 109–119.

[5] M. Sobesy, and J.S. Meschke, Virus survival in the environment with special attention to survival in sewage droplets and other environmental media of fecal or respiratory origin. (2003). Available from: http://www.iapmo.org/common/pdf/ISS-Rome/Sobsey_Environ_Report.pdf

[6] J. Lukasik, T. Scott, D. Andryshak, S. Farrah, A. Farrah, Influence of Salts on virus adsorption to microporous filters, Appl. Environ. Microbiol. 66(7) (2000) 2914–2920.

[7] R.C. Bales, S. Li, K.M. Maguire, M.T. Yahya, C.P. Gerba, MS-2 and poliovirus transport in porous media: Hydrophobic effects and chemical perturbations, Water Resour. Res. 29 (1993) 957–963.

[8] P.A. Shields, S. Farrah, Characterization of virus adsorption by using DEAE-Sepharose and Octyl-Sepharose, Appl. Environ. Microbiol. 68(8) (2002) 3965–3968.