Silver Release from Nano-enabled Polymer Membranes

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Background

Membrane-based filtration systems have increasingly been used due to ease of operation and reliability, but use is hindered by biofouling resulting in increased energy costs and shortened membrane life. Incorporating antimicrobial nanomaterials into membranes offers a potential solution to this hindrance. Silver nanoparticles (nAg) can be incorporated into membranes as a filler to deactivate microorganisms during water filtration thus reducing membrane fouling. The antibacterial effects of nAg is primarily related to the released ionic silver produced as the silver nanoparticles oxidize and dissolve, but there is concern that these effects can carry over to unintended subjects in the environment. Here we aim to estimate the release of silver from varying polymeric membranes in support of future risk assessments.

Figure 1. Examples of point of use nAg enabled water filters on the market.

Life Cycle Perspective

Applying a life cycle perspective is a holistic approach that considers impacts of a material throughout its full life (i.e. cradle to grave). The process looks at a range of inputs and effects for each stage within the life cycle. Each having its own set of potential inputs (energy water and chemicals) and environmental impacts (toxic releases, ecological effects and greenhouse gas emissions).

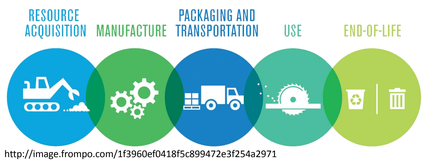

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Figure 2. Stages of Life Cycle Assessment.

Research Objectives

- Assess the release rate across the life stages of nAg embedded polymeric membranes and evaluate how changes in pore size and polymer type affect estimated release.
- Determine the efficacy of nAg enabled membranes before and after exposure to varying environmental conditions and qualitatively compare this added benefit to the potential risk of exposure.

Potential Risk: Assess Release across Life Stages

APPROACH

- Synthesize membranes embedded with Tween 20 nAg (2% wt. to polymer) by wet phase inversion: (1)Polysulfone [PSF], (2) PSF+ Polyvinylpyrrolidone [PSF+PVP]; (3) polyvinylidene fluoride [PVDF]
- Measure total silver released in coagulation baths by ICP-MS
- Membrane characterization: SEM, XPS, permeability, and contact angle

- Perform passive release test by submerging coupons into 100ml of DI water and placing on shaker table for 14 days
- Aliquots of matrix analyzed by ICP-MS for total and dissolved silver
- Dissolved silver samples are centrifuged in 30 kDa centrifugal filters for 30 mins at 5000 RPM

Perform passive release test w/ varying matrices (Na_2S, NaCl)
- Toxicity characteristic leaching procedure (TCLP)

Raw Materials & Manufacturing → **Product Use** → **End of Life**

Figure 3. SEM-EDS Mapping of Silver and Carbon for PSF+PVP membrane

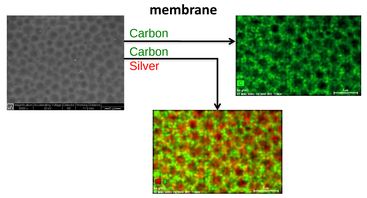


Figure 4. Silver Released during PSF (2%nAg) Membrane Fabrication

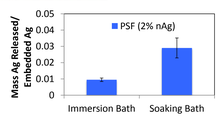


Figure 5. Silver Released in 14 Day Passive Release Experiment

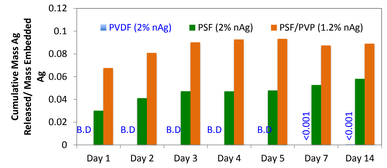
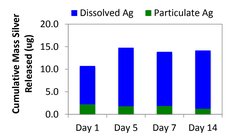


Figure 6. Dissolved vs. Particulate Silver Released for PSF+PVP Membrane



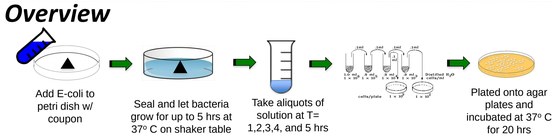
PRELIMINARY RESULTS

Added Benefit: Antibacterial Test for Efficacy

Approach:

- Assess bacterial inhibition for virgin and embedded membranes
- Compare antibacterial properties over time (initial vs. 14 days in DI water)
- Perform inhibition tests on coupons exposed to NaCl and Na_2S

Method Overview



Preliminary Results:

Figure 7. Slight bacteria inhibition displayed in all 3 embedded membranes after 1 hour

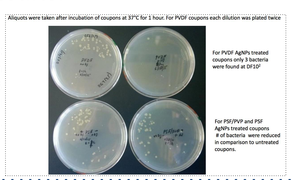


Figure 8. Bacteria inhibition after 3 hours.

Summary

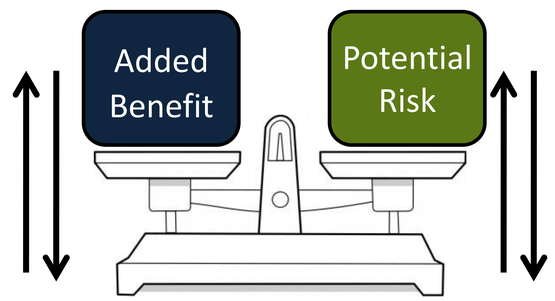
The overall aim of this study is to compare the nano-enabled added benefit with the potential risk/exposures of silver release from nAg membranes. Preliminary results suggests that:

- Silver is primarily released within the first day for polysulfone membranes and stops within 14 days, but for PVDF membranes measureable silver is not released for 7 days
- Polysulfone membranes with larger pore sizes release higher amounts of silver (ratio released Ag/total Ag)
- Nano-enabled membranes display more antibacterial properties compared to 'virgin' membranes, 1.6 – 2 log reduction achieved

Future Direction

- Perform kinetic release studies for polysulfone membranes
- Complete end of life and efficacy tests
- Obtain market nAg point-of-use filters, assess silver release and loading to compare against estimates for synthesized materials

Compare the nano-enabled benefit to risk



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