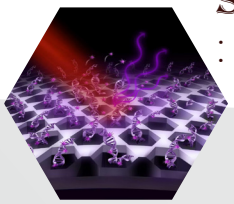
NanoTechnology in Action: Enhanced Membrane Cleaning

SHOWCASING WATER INNOVATION
: Case Study



Naturally Superior

" The new bi-functional nanostructured electrode technology developed in this project has effectively integrated two advanced processes, photocatalysis and electrocatalysis, into one highly efficient system for water treatment and purification, which has great potential for the effectiveness of membrane cleaning."

Aicheng Chen, PhD, FRSC(UK), FISE
Professor & Canada Research Chair
Department of Chemistry, Lakehead University

Bi-functional Electrode Performance Results

- The catalyst nano tubes have excellent stability with high efficiency and effectiveness
- 20% reduction Membrane cleaning time using sodium hypochlorite and bi-functional electrode due to increase in cleaning efficiency
- Inorganic reduction occurred during sodium hypochlorite clean eliminating the need for acid clean, a decrease of 30% in chemical use and wastewater

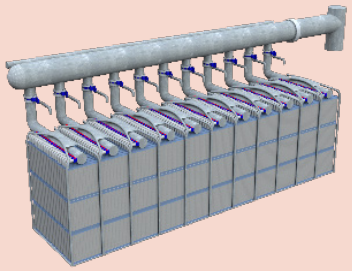
Lakehead UNIVERSITY

CITY OF Thunder Bay
Superior by Nature

Ontario

This project has received funding support from the Government of Ontario. Such support does not indicate endorsement by the Government of Ontario of the contents of this material.

Background



The Bare Point Water Treatment Plant (WTP) employs ultrafiltration membrane technology to produce potable water for the City of Thunder Bay. On average, the plant treats 44 MLD (million litres per day) of water. Dirt and pathogens that are removed from the water adhere to and impact the membrane surface. Foulants include inorganic substances, organic matters, colloidal/particulates, and microorganisms that adhere on the membrane surface or inside the membrane matrix that causes degradation of membrane performance and decreases membrane life span. To maintain the membranes, the Bare Point WTP treatment process produces 3 to 5 MLD of backwash waste water and 0.4 MLD of membrane cleaning waste water daily. The treatment plant employs sodium hypochlorite, citric acid and phosphoric acid in its membrane cleaning processes. Bare Point operates and maintains 5 membrane process trains for water treatment. To maintain the membranes each year, there are approximately 1,825 washes at 100 mg/L chlorine, 60 recovery washes at 500 mg/L chlorine and 30 citric/phosphoric acid washes. As part of the membrane cleaning process, approximately 146 million litres of water are added to the plant's waste stream annually.

Challenge

An operational challenge of the membrane filtration process is keeping the membranes clean to avoid costly replacements. Membrane Water Treatment Plants use a combination of backwashing and chemical cleaning processes to remove the organic and inorganic materials (foulants) that adhere to the membrane surface. The organics are removed during a 6 hour heated alkaline chemical clean (500 mg/L sodium hypochlorite) followed by a 6 hour heated acidic chemical clean (2000 mg/L citric acid pH depressed to 2 pH with a strong acid). This process is effective although time consuming with an energy cost for heating the water. Although a second challenge is that the cleaning process is not 100% effective, leaving a small amount of foulants (termed as irreversible fouling) to slowly accumulate over time (10 years) and reduce membrane permeability, ultimately leading to increased plant energy consumption, reduced plant capacity, and increased frequency of chemical membrane cleans. The result is that as membranes age, plant operational and capital costs increase.

Adding to the complexity of looking for alternative solutions is that the cleaning of organic and inorganic materials happens at opposite extremes of the pH scale. A pH of 11 is required for organic removal and a pH of 2 for inorganic removal.

Also, the fouling removal process can increase operating costs and decrease membrane life span. Research work by Dr. Liao et al has demonstrated that the sodium hypochlorite (hypo) used for recovery cleans are degrading the structure of the membrane polymer polyvinylidene difluoride (PVDF) and that hypo recovery cleans at 500 mg/L are contributing to inorganic deposition on the membrane surface. The source water for the Bare Point WTP has a low alkalinity which results in a high Langiers Saturation Index during the 500 mg/L hypo recovery cleans, which means there is a high scaling potential during the hypo recovery cleans.

Ecosystem Regeneration Through Innovation

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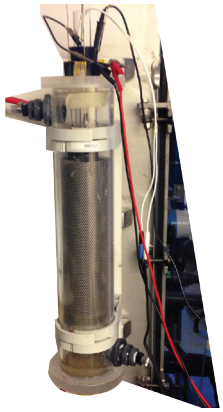
Project Goals

The goal of the project was to demonstrate a novel membrane cleaning technology that would improve the cleaning efficiency and reduce operational costs. Funding for the project was received from the Ontario Ministry of the Environment and Climate Change's Showcasing Water Innovation Program.

Solution



Dr. Aicheng Chen, Professor of Chemistry and Canada Research Chair of Material & Environmental Chemistry, and his research team at Lakehead University (Thunder Bay Campus) have created a novel bi-functional technology for removing toxicity from wastewater effluents. The bi-functional technology effectively integrates two advanced water purification methods: photochemical degradation and electrochemical oxidation. Photochemical degradation uses light and a photocatalyst to break down organic pollutants and electrochemical oxidation uses electricity and an electrocatalyst to remove inorganic contaminants. Their innovative bi-functional technology has demonstrated when these two processes are combined, the treatment efficiency is much greater than either method alone.

The bi-functional nature of the technology suggested that both organic and inorganic reduction could be accomplished in a single membrane cleaning step.

The bi-functional electrode was developed at Lakehead University as a device to treat wastewater. The design incorporates a UV light source and an electrode in a battery type circuit. On the surface of the electrode an electrocatalyst is combined with a photocatalyst. The first stage of the project was a modification of the catalysts to increase efficiency and stability (long life). The second stage was learning how to plate the electrocatalyst as a thin nanoporous structure onto the electrode. Success in both of these areas in the laboratory at Lakehead University led to an electrode that was more stable and more reactive than the original electrode used for the lab scale that lead to the application for the Showcase Innovation grant. The pilot scale bi-functional electrode used a nano tube structured catalyst.

Results from a membrane cleaning study at the Bare Point WTP indicated the bi-functional probe could be used to increase the efficiency of the cleaning process by reducing cleaning time and frequency. For this project, electrodes were fabricated and installed in a pilot water treatment plant at the Bare Point WTP, and numerous membrane cleaning cycles were performed to evaluate the effectiveness of the technology for improving the membrane cleaning process.

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Results

Preliminary results of the bi-functional electrode used during recovery clean include:

- Bi-functional electrode results show that both organics and inorganics are removed during a single Sodium Hypochlorite clean of 6 hrs with no pH adjustment.
- Chemical savings of 50% by increase in Hypo clean efficiency and elimination of citric clean
- Potential Membrane Life Cycle Increase
- Waste water reduction of 33% due to elimination of citric clean

Application for Ontario Municipalities

Ontario communities can benefit from the following lessons of this project:

- Traditional cleaning of membranes is a time consuming process and creates a large volume of waste water. In addition, over time, the cleaning solutions deteriorate the membrane polymer resulting in a large capital cost for replacement.
- Partnerships lead to innovative solutions especially when a relatively new solution is needed due to the concerns of adapting to evolving research results of a new technology like ultrafiltration for drinking water.
- The bi-functional electrode has the potential to provide organic and inorganic cleaning in a single recovery clean.

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