Removal of Micropollutants From Municipal Wastewater: Lake Simcoe / The Regional Municipality of York Pilot Project

Solutions for the Wastewater Industry

Keswick Water Pollution Control Plant

High Level Results

- Only some wastewater micropollutants may be removed with UV photolysis alone and may require UV doses up to 100 times a typical UV disinfection dose.
- UV/H_2O_2 is a suitable treatment option for difficult compounds but can significantly increase overall wastewater plant costs.
- Plant costs were marginally improved with pretreatment and cost savings are influenced by the degree to which pretreatment improves the UV transmittance of the wastewater.
- Highest cost savings observed with UV + 100 mg/L H_2O_2 with pretreatment.

"A collaborative approach and an understanding of plant-specific information are critical in treating micropollutants."

Laura Meteer
Water Quality Analyst
The Regional Municipality of York

Project Context

Micropollutants are a class of contaminants that include pharmaceuticals, personal care products, endocrine disruptors, and household cleaners. They are of growing concern as high concentrations may affect aquatic ecosystems by disrupting fish spawning patterns and reproductive activities. Effluent from wastewater treatment plants are a low level source of these pollutants in lakes and streams. While micropollutants are not currently regulated, reducing their release would be a proactive step in ensuring aquatic ecosystem health. Initiatives with this goal are relevant to Lake Simcoe as it is the largest and one of the most intensively fished Ontario inland lakes. Programs are ongoing to maintain the long-term health of the lake under the *Lake Simcoe Protection Act, 2008* and Lake Simcoe Protection Plan, however, additional work is required to understand the potential impact of micropollutants on the lake.

Challenge

Micropollutants are not regulated. Nevertheless, given the ongoing concerns for their possible impact on the environment, a feasible, economical, and practical solution that could be used to reduce their release would be a proactive step.

Project Goals

The goal was to demonstrate a UV-based advanced oxidation process (AOP) for wastewater treatment that would reduce the release of micropollutants to the environment. An associated goal was to explore methods to make this process more cost-effective by combining coagulation/activated carbon adsorption with the UV-AOP treatment.

Solution

One effort to prevent the release of micropollutants into the environment is through municipal wastewater treatment, since this is a common source of emission. Numerous studies have shown that advanced oxidation processes (AOPs) are very effective for the degradation of micropollutants. Typical AOPs include ultraviolet light (UV)-based or ozone (O_3)-based AOPs such as using hydrogen peroxide with ultraviolet light (UV/H_2O_2) or ozone (O_3/H_2O_2), ozone and UV (O_3/UV), chlorine and UV (HOCl/UV), as well as the Fenton's reagent (Fe^{2+}/H_2O_2) and photocatalysis using titanium dioxide and UV (TiO_2/UV). All AOPs involve the generation of hydroxyl radicals ($^{\bullet}OH$) which are very strong oxidants that can destroy a wide range of compounds. In Ontario, UV disinfection is typically the preferred alternative for disinfection of the final effluent due to strict regulations for residual chlorine concentrations. Therefore, UV-based AOPs would be a practical choice for integrating AOPs into wastewater treatment facilities. For this study, UV/H_2O_2 and UV/TiO_2 advanced oxidation treatment were evaluated. Different combinations of H_2O_2 doses and pretreatment options (enhanced coagulation and activated carbon adsorption) were also investigated to determine which combination would provide the most cost benefit.

Pilot-Scale Calgon Carbon Rayox® Advanced Oxidation Batch Reactor

Pilot-Scale Purifics® UV/TiO_2 Reactor

Results

Pilot-scale experiments showed that some micropollutants (naproxen, 17β-estradiol, sulphamethoxazole, diclofenac, and clofibric acid) were effectively removed (>90%) with UV photolysis alone, although UV photolysis doses of up to 2400 mJ/cm^2 were required (Figure 1). This is about 100 times more UV energy than is required for typical UV disinfection. Caffeine and carbamazepine required advanced oxidation (UV/H_2O_2 or UV/TiO_2). A 90% removal of caffeine and carbamazepine was achieved with a UV dose of 3193 mJ/cm^2 and 2615 mJ/cm^2 respectively at the H_2O_2 dose of 20 mg/L. With UV/TiO_2, removal of both caffeine and carbamazepine to below the detection limit was achieved with a UV dose of 3000 mJ/cm^2 at a TiO_2 dose of 1 g/L.

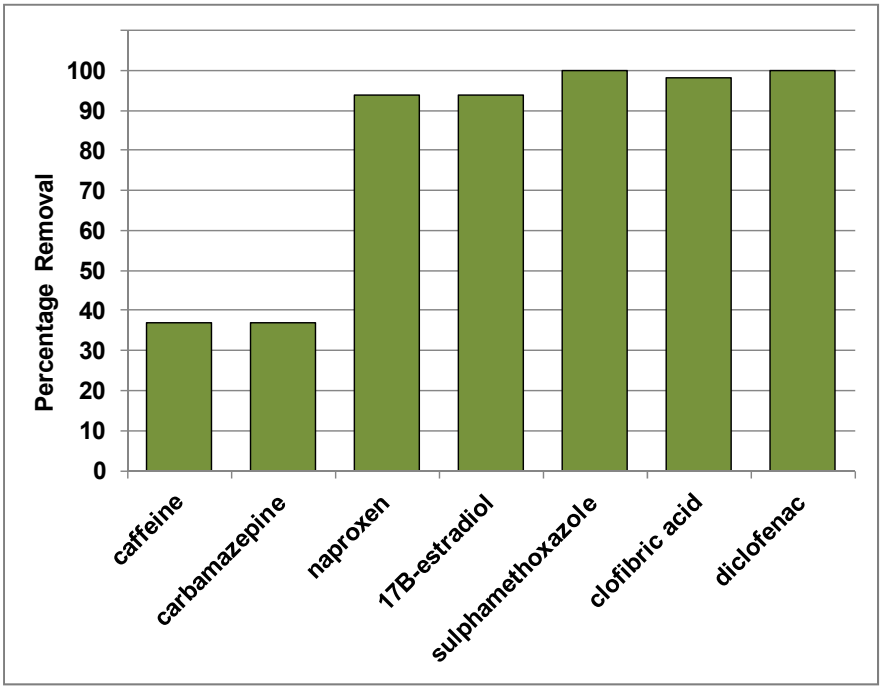

Figure 1: Percentage removal of the micropollutants with UV alone (maximum UV Dose = 2400 mJ/cm^2)

Pretreatment of the secondary effluent to reduce the concentration of organic matter decreases the oxidant demand and AOP dose requirements for treating the micropollutants, thereby improving the effectiveness of the AOP process. The implications of pretreatment were assessed experimentally at concentrations of 0 to 20 mg/L H_2O_2, and cost modelling was performed to estimate the impact on costs at higher H_2O_2 concentrations of 50 mg/L and 100 mg/L, and for a wastewater for which a higher UV transmittance (UVT) of 84%/cm (versus 74%/cm) is obtained with pretreatment. For this study, the cost of pretreatment did not fully justify its benefits although the lowest cost was obtained with pretreatment followed by UV/H_2O_2 treatment at 100 mg/L H_2O_2 (Figure 2). The study also found that the cost savings were improved with a higher UVT. However, it is important to note that for other plants, different combinations of pretreatment options and H_2O_2 doses may be more suitable for their respective water characteristics. Overall, using UV-AOP for micropollutant removal can be costly, as targeting a 90% removal of carbamazepine increased the overall treatment plant costs (20 year Net Present

Value) by 16% (with 10 mg/L H_2O_2) and 12% (with 20 mg/L H_2O_2) in this case study. However, model estimates in this study found that higher H_2O_2 doses of 50 mg/L and 100 mg/L H_2O_2 only increased overall plant costs by 9% and 8% respectively.

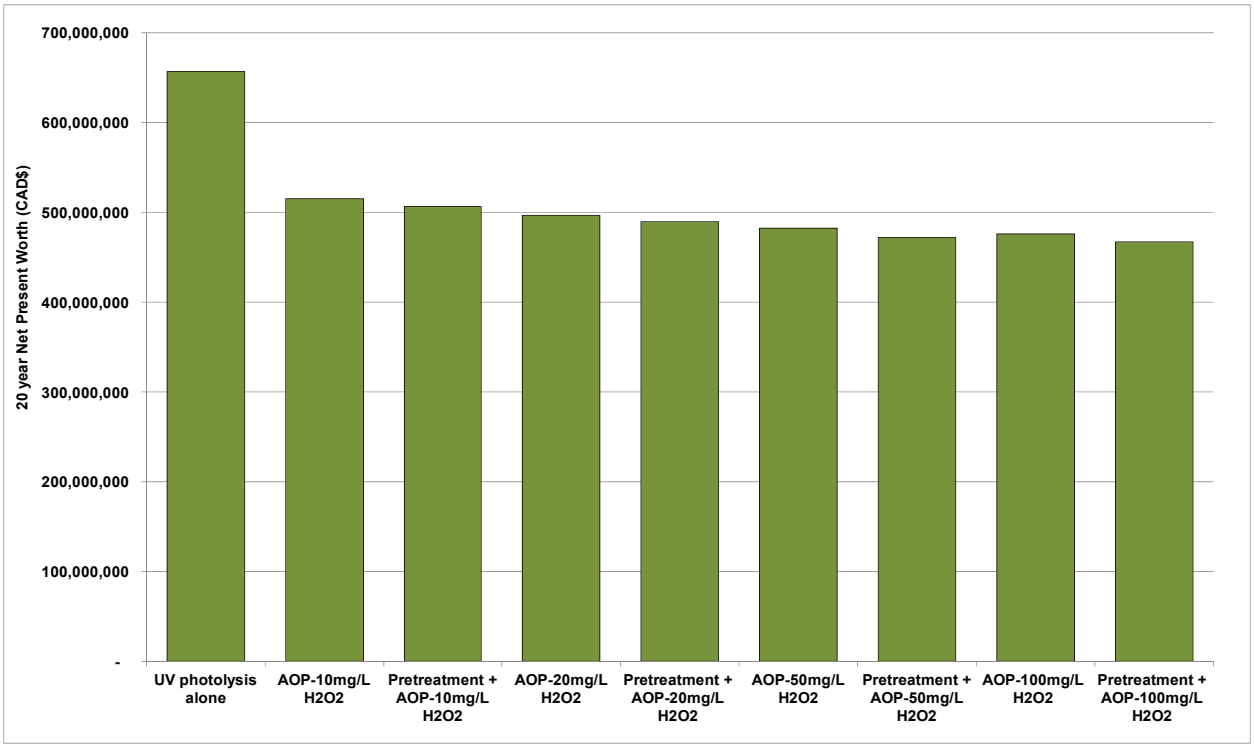

Figure 2: Comparison of overall costs for different treatment scenarios with UV/H_2O_2 for 90% degradation of carbamazepine

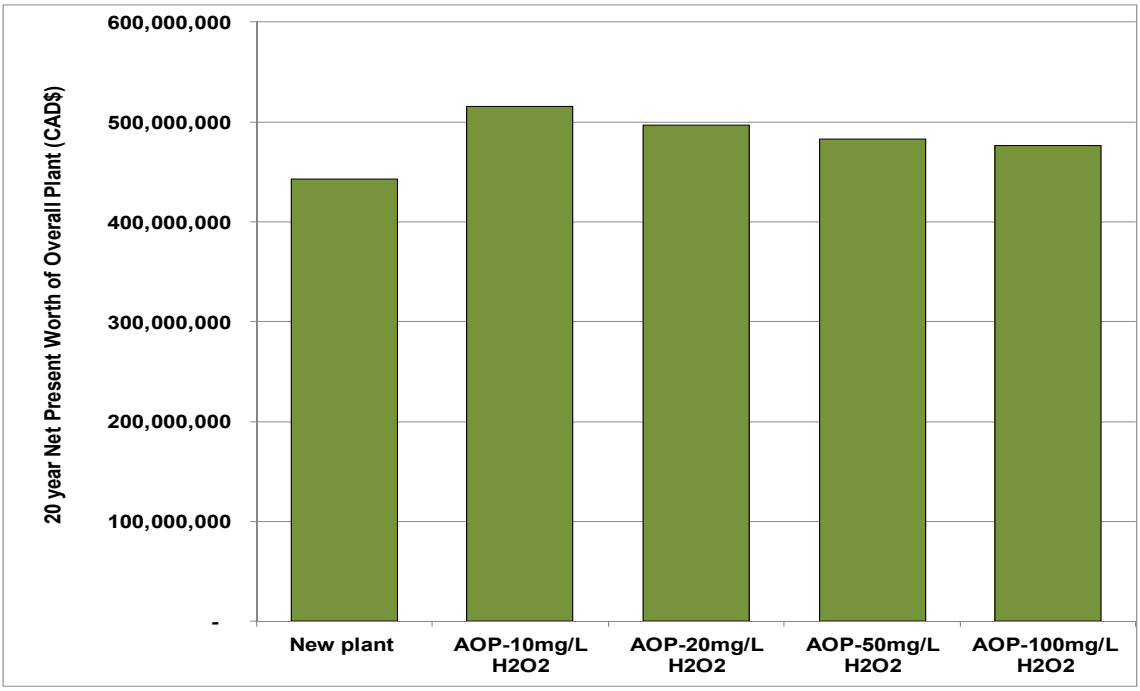

Figure 3: Impact of different UV-AOP systems on overall plant costs for 90% degradation of carbamazepine

A document entitled "Guidance Document for Integrating UV-based Advanced Oxidation Processes into Municipal Wastewater Treatment Plants" has been developed as a component of this project. The document provides additional information on the case study and the results, includes criteria that should be considered when evaluating the use of UV-based AOPs for a full-scale wastewater treatment plant, and briefly outlines an approach for assessing costs and energy requirements. This document will be made available to Ontario municipalities through the Drinking Water Research Group, University of Toronto.

Next Steps

The Regional Municipality of York will initiate a seasonal monitoring program to characterize the micropollutant content of the wastewaters of the facilities managed by the Region. The information obtained from the monitoring program will subsequently be used to conduct a comprehensive feasibility study of suitable, fiscally responsible options (such as advanced oxidation) for treating micropollutants (if necessary) in wastewater effluents.

Application for Ontario communities

The information generated by this project and the comprehensive feasibility study can be used by other municipalities that are interested in assessing treatment options for micropollutants in their wastewater.

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