Research has shown that the process of disinfecting drinking water to kill and/or inactivate pathogens may have the unintended consequence of forming disinfection byproducts (DBPs). When the disinfectant free chlorine is used, over 500 different DBPs have been identified. Trihalomethanes (THMs) and haloacetic acids (HAAs) account for a significant portion of the total DBPs formed in the reaction of free chlorine with natural organic matter (NOM) in water and are associated with human health concerns. They are regulated in many countries including Canada.

DBP formation can be managed in municipal drinking water systems through precursor removal and adjustment of disinfection parameters. Disinfection parameters that affect DBP formation include type and concentration of disinfectant, temperature, pH and contact time. DBP precursors, especially those of THMs and HAAs, include humics (hydrophobic) and other compounds with UV$_{254}$ absorbance. Enhanced coagulation is the best available technology that is economically feasible for removal of DBP precursors (hydrophobic NOM), where coagulation parameters are adjusted to achieve maximum DBP precursor removal. Advanced oxidation processes combining ozone, hydrogen peroxide, and/or UV light are also emerging as effective ways to degrade contaminants in water including DBP precursors. AOPs utilize the hydroxyl radical which is a very strong oxidant; however the AOPs currently available are chemically and energetically intensive.

TiO$_2$ photocatalysis has been shown to reduce THM and HAA formation by degrading DBP precursors and also by providing disinfection capability. TiO$_2$ absorbs light and dissipates it through the excitation of an electron to its conduction band, creating what is termed an electron/hole pair. The electrons and holes can then directly degrade NOM in the water, or can create reactive oxygen species (ROS) such as the hydroxyl and superoxide radicals that can then degrade NOM. TiO$_2$ requires low chemical and energy inputs; needing only UVA light and the TiO$_2$ catalyst. However, the process is only 4% quantum efficient, and the TiO$_2$ must be recovered from the water after treatment.

Three preliminary experiments have been conducted with P25 TiO$_2$, an industry standard TiO$_2$ nanoparticle powder. The experiments were conducted in continuously stirred batch reactors with a water volume of 200 mL. The SS150AAA Solar Simulator from Photo Emission Tech., Inc. was the light source for the experiments. It matches the natural solar electromagnetic radiation spectrum reaching the surface of the earth with an irradiance of approximately 1000
W/m² “one sun”, +/- 20%. The UVA portion (30 W/m²), equals a dose of 54 kJ/m² for every 30 minutes of treatment. The experiments compared two water sources and two concentrations: synthetic water was treated with TiO₂ at a concentration of 0.5 g/L in suspension, and Otonabee River water was treated with TiO₂ at concentrations of 0.5 g/L and 0.15 g/L in suspension.

Following photocatalysis, the water was filtered and the DOC and UV<sub>254</sub> absorbance were measured. The DBP formation potential was determined using the uniform formation condition (UFC) chlorination test. The UFC parameters are: pH of 8, temperature of 20 °C, 24 hour contact time, and 1 mg/L chlorine residual. The UFC chlorination test was carried out with untreated raw water, after a 30 minute dark adsorption phase, and after photocatalytic treatment (30, 60, 90 and 120 min intervals). THMs and HAAs were analysed with gas chromatography following liquid/liquid extraction.

Chloroform (trichloromethane), dichloroacetic acid and trichloroacetic acid were the only THMs and HAAs identified. Longer irradiation times typically showed steady decreases in formation potential however some DBPs had similar formation potentials with 90 and 120 minutes of photocatalysis and this may be because only recalcitrant compounds remained. It is suspected that the increase seen after some irradiation is caused by original NOM, intermediate or final degradation products that are desorbed into the water upon irradiation and react with chlorine. The two Otonabee River water experiments with TiO₂ in suspension at concentrations of 0.15 g/L and 0.5 g/L had similar final % removal values for the DBPs. This may mean that there are other limiting factors to this treatment such as available photons, or that the treatment system has reached its capacity and only recalcitrant compounds remained. Comparing the synthetic and Otonabee River waters experiments, better % removal of TCM and TCAA was observed in synthetic water, while DCAA had higher % removal in Otonabee River water. Specific DBP, the DBP normalized to DOC, decreases with time supporting the claim that TiO₂ preferentially degrades DBP precursors. DOC and SUVA also decreased, but a correlation of specific DBP formation potential to SUVA was not established.

In the next few months, different source waters will be tested and results from this winter will be compared to results in the spring and summer. Different nanomaterials will be tested as they are fabricated, with a plan to test nanowires, N or I doped TiO₂, and membrane filters. With regard to membrane filters, a reactor that is capable of simulating cross-flow and dead-end filtration configurations is being assembled. Liquid chromatography – organic carbon detection (LC-OCD) analysis will be completed alongside DOC and UV<sub>254</sub> measurements to connect subsequent DBP formation potential decreases with specific classes of precursors. Ultimately, the results of these experiments are expected to add to the body of existing photocatalytic literature and research in the removal of drinking water contaminants to ensure secure community water systems.