The Use of UV-LED in Drinking Water Treatment as a Response to Climate-Driven Increases in Natural Organic Matter

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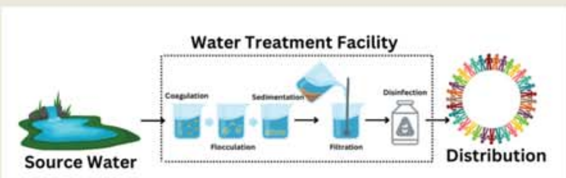
This poster depicts one semester worth of co-op work contributing to Ryan Swinamers PhD at the Centre for Water Resources Studies, Dalhousie University, Department of Civil and Resource Engineering.

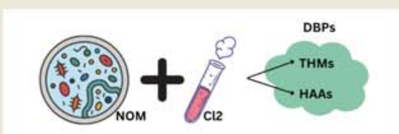
01. Introduction

Water Treatment Process at the J.D Kline (JDK) Water Treatment Plant:
Aluminum sulfate (alum) is added as a coagulant to raw lake water and the water is mixed at various rates to cause flocculation and sedimentation of particles. The water is then run through an anthracite-sand biofilter and disinfected with chlorine.



Impacts of Climate Change on Source Water Conditions in Atlantic Canada:
2023 saw **increases in natural organic matter** (NOM) levels greater than 67% as a result of climate-driven dry spring and wet summer (Swinamer et al. 2024). Increased NOM requires subsequent increases in alum dosing. From 1999-2023, some plants saw up to an 8x increase in alum dosage. This increase comes with a corresponding increase in CO_2 emissions.

Formation of **Disinfection By-Products** (DBPs):
In the final stage of water treatment (disinfection), residual NOM reacts with the chlorine to create DBPs. Common DBPs in drinking water are Trihalomethanes (THMs) and Haloacetic Acids (HAAs) (both toxic at certain levels). Levels of these DBPs are used to regulate treatment facilities.



02. Objective

This study aims to test UV-LED as a potential method of eliminating NOM and preventing further increases in DBPs that occur as a result of residual NOM reacting with the chlorine added in the final step of drinking water treatment.

Related literature

CDC. 2024. "How Water Treatment Works." Drinking Water. September 3, 2024. https://www.cdc.gov/drinking-water/about/how-water-treatment-works.html.
"Dal Water Home | Centre for Water Resources Studies." n.d. https://centreforwaterresourcesstudies.dal.ca/.
Swinamer, Ryan, Lindsay E. Anderson, Dave Redden, Paul Bjorndahl, Jessica Campbell, Wendy H. Krkošek, and Graham A. Gagnon. 2024. "Climate-Driven Increases in Source Water Natural Organic Matter: Implications for the Sustainability of Drinking Water Treatment." Environmental Science & Technology 58 (27): 11958–69. https://doi.org/10.1021/acs.est.4c01894.

03. Methodology

Clearwell water from the JDK treatment plant was collected in large amber jugs and combined with various levels of hydrogen peroxide or chlorine based on the experiment at hand. This water was run through a custom-made AquiSense UV-LED flow cell, affectionately referred to as the 'toaster', at several different UV power levels and flow rates. Water collected was first tested for residual H_2O_2 or Cl_2 concentration prior to other water quality parameters.

experimental conditions:

UV-LED power (%)	water flow (mL/min)
0	0
20	100
50	100
100	100
100	50
75	50

H_2O_2 and Cl_2 levels (mg/L): 0, 3, 5

The water quality parameters were measured for the influent water and the effluent water from each treatment.

water quality parameters:

- **UV-254 absorption***
- **UV-275 absorption**
- **turbidity**
- **pH**
- **fluorescence exitation-emission matrix spectroscopy**
- **chemical oxygen demand**
- **dissolved organic carbon (DOC) levels***
- **total organic carbon (TOC) levels***
- **DBPs (HAAs and THMs)***

*most indicative of experimental effects, used for preliminary results

04. Results/Findings

This study is in preliminary stages and many results are still to come.

Early results:

- decreases in UV-254 absorbance as great as 0.014 cm^-1 in H2O2 experiments
- decreases in UV-254 absorbance as great as 50% under in Cl2 experiments
- decreases in UV-275 absorbance as great as 0.015 cm^-1 in H2O2 experiments
- TOC data shows minimal change after exposure to UV-LED

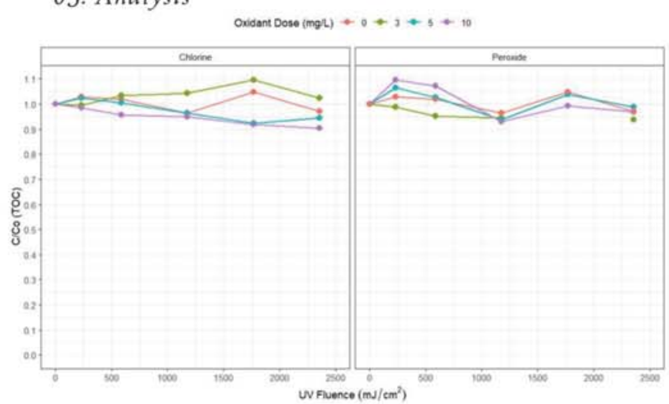
06. Conclusion

Early results indicate that the UV-LED treatment is breaking down the NOM (decreasing UV-254) in the water but not mineralizing it (stagnant TOC levels).

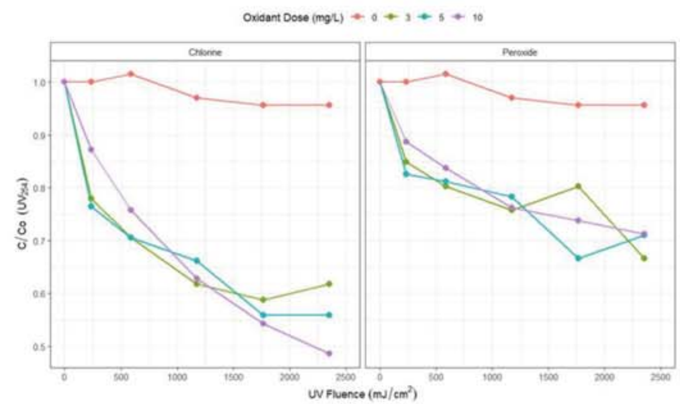
Although this research is still in it's early stages of analysis, preliminary results are promising. This technique could revolutionize drinking water treatment, as it already has with wastewater treatment.

This research is vital to prevent further increases in DBPs that occur as a result of residual NOM reacting with the chlorine added in the final step of treatment. Ongoing experiments will provide data replication and results under alternate conditions.

05. Analysis



Analysis of change in TOC levels under different UV treatments, where the y-axis is the influent value divided by the effluent value (percent remaining). This analysis indicates that levels of TOC are not significantly impacted by UV-LED treatment.



Analysis of change in UV-254 absorption under different UV treatments, where the y-axis is the influent value divided by the effluent value (percent remaining). This analysis indicates that levels of UV-254 absorption decrease following the UV-LED treatment.