222 nm KrCl* Driven Advanced Oxidation for Reverse Osmosis Pretreatment: Fouling Control and Chemical/Pathogen Abatement

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UV222 pretreatment of reverse osmosis (RO) membranes can decrease membrane fouling, while providing significant micropollutant removal and virus inactivation

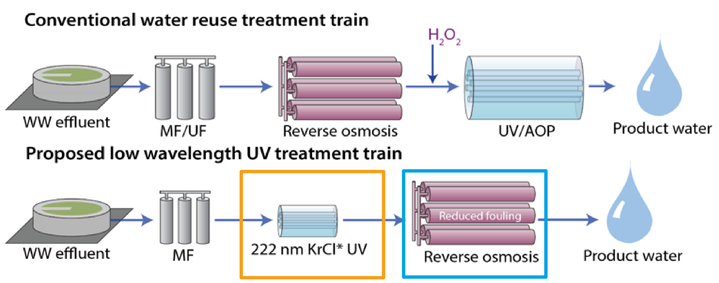
Background and Rationale

KrCl* excimer lamps are a novel UV light source emitting at 222 nm. Nitrate and organic matter absorb strongly in the Far-UVC range (<230 nm) and act as photosensitizers to produce hydroxyl and other radicals. Direct UV and chemical reactions with hydroxyl radicals alter organic matter, decreasing the aromaticity and molecular size while destroying chemical contaminants and pathogens. Thus, UV222 irradiation of wastewater effluent may decrease the susceptibility of EfOM to foul downstream reverse osmosis membranes.

Objectives

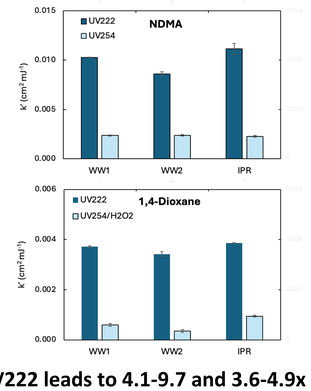
1. Determine the extent of fouling mitigation achieved by UV222 pretreatment
2. Investigate contaminant degradation and virus inactivation during UV222 RO pretreatment
3. Explore transformation to effluent organic matter (EfOM) character and establish relationships between EfOM properties and membrane fouling
4. Design and test a UV222 flow–through reactor

Proposed Innovation



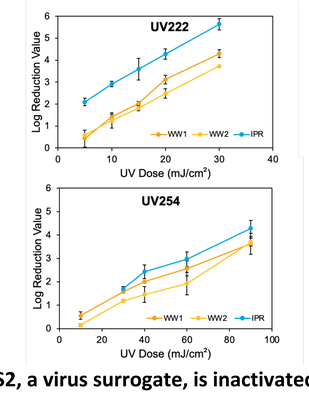
Water Reuse Treatment Goals

MICROPOLLUTANT DEGRADATION



UV222 leads to 4.1-9.7 and 3.6-4.9x faster degradation of 1,4-D and NDMA, respectively

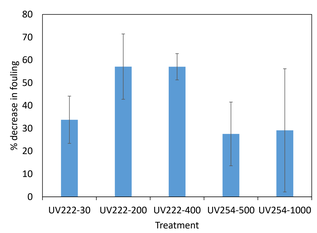
VIRUS INACTIVATION



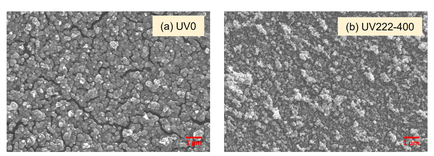
MS2, a virus surrogate, is inactivated ~4x faster by UV222 than UV254 in partner wastewaters

Treatment Train Synergy

FOULING MITIGATION

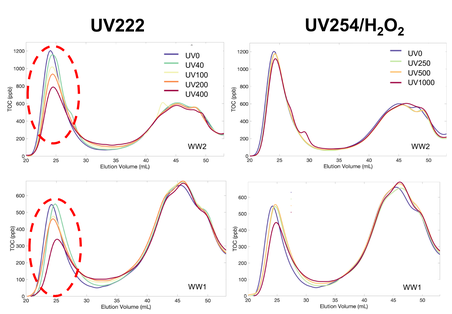


UV222 pretreatment results in 58% fouling reduction, compared to 28-29% fouling reduction from comparable UV254 treatments.



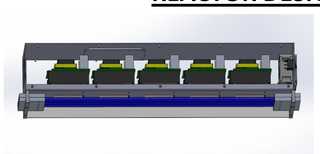
SEM/EDS reveal that UV222 pretreatment results in a less dense fouling layer with more intermixing between organic and inorganic components compared to no UV pretreatment

ORGANIC MATTER TRANSFORMATION



UV222 degrades the large molecular weight fraction in EfOM more than conventional UV254/H_2O_2

REACTOR DESIGN



Future work will investigate the scale-up of KrCl* lamps for pilot applications

NAWI CONNECTIONS

Period of Performance: December 2023– June 2026

Challenge Area/Topic Area:

The topic area of Process Innovation & Intensification with a focus on electrified systems is embodied in our research approach. UV treatment is an electrified process that can utilize renewable energy for power, and it represents a modular, scalable and innovative approach for desalination pretreatment systems, with additional benefits.

NAWI Leverage:

NAWI partners have enabled access to key wastewater resources for this study. NAWI cross-cutting tools such as WaterTAP are being leveraged for techno-economic analysis.

KEY FINDINGS AND FUTURE WORK

Key Findings:

- Virus inactivation and contaminant degradation in wastewater is accelerated by UV222 compared to UV254/H_2O_2
- Large molecular weight compounds are significantly transformed by UV222, potentially leading to reduced membrane fouling
- UV222 pretreatment leads to 29% improved fouling reduction (measured by flux decline and baselined to untreated case), compared to UV254/H2O2 at comparable fluences for contaminant degradation

Future Work

- Elucidate the mechanisms of organic fouling using model foulants
- Investigate the impact of UV222 on biofouling using Pseudomonas
- Continued testing and evaluation of flow-through reactor
- Integrate results into NAWI WaterTap tool to assess economic feasibility of novel UV222 RO pretreatment process

REFERENCES

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Liu, B., Mullen, L., Payne, E.M., L.; Linden, K.G. Accelerated Ultraviolet Treatment of Carbamazepine and NDMA under 222 nm Irradiation. *Environ. Sci. Technol*., 2023, 57(47), 18909-18917.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Alliance for Water Innovation (NAWI), funded by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), Industrial Efficiency and Decarbonization Office under Funding Opportunity Announcement DE-FOA-0001905. Partners on this research include UV suppliers and collaborators Ushio America Inc. and Eden Park Illumination Inc., Dupont, and water partners Orange County Water District, Aurora Water, City of Boulder Utilities, and Produced Water Recycle LLC.

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