# Abstract

## EFFICACY OF DIRECT OZONE CONTACT PAIRED WITH MEMBRANE FILTRATION FOR MUNICIPAL WASTEWATER TREATMENT

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Conventional biological secondary treatment has long served as the cornerstone of municipal wastewater treatment, yet it presents challenges of energy intensity, biological upsets, large spatial footprint, and variable removal efficiency depending on influent conditions. Ozonation and membrane processes are widely recognized as effective advanced treatment technologies, capable of reducing trace organics, and pathogens. However, direct ozonation as a replacement for biological secondary treatment has not been comprehensively investigated. This dissertation evaluates the feasibility of employing direct ozone contact paired with reverse osmosis (RO) as a substitute for activated sludge.

First, an evaluation of the kinetics of direct ozone contact on municipal primary effluent at bench scale (1.5 L ozone contactor) was conducted across a range of temperatures and compared to activated sludge. Results demonstrated that ozone exhibited rapid reaction kinetics, achieving reductions in chemical oxygen demand (COD) comparable to biological treatment with nearly a 75% lower retention time, regardless of the temperature in the range tested (7 to 34°C).

The second component was also at bench scale (3 L ozone contactor) and investigated system integration by comparing two treatment trains: direct ozone contact followed by RO, versus activated sludge with RO. This evaluation revealed differences in RO fouling behavior and permeate quality, highlighting the ways in which ozone pretreatment alters the organic matrix relative to biological processes and improves downstream membrane performance.

The last component was at pilot-scale (399 L ozone contactor; 3.78 L/min flow) and assessed the performance of direct ozone contact with RO for typical wastewater quality parameters, including oxygen demand, suspended solids, organic matter, and disinfection. Energy usage was also quantified, with a nominal energy usage >10x that of typical conventional reuse treatment, although optimizations are discussed to potentially reduce energy usage of direct ozone contact by >67%. Pilot results demonstrated that ozone-RO treatment can meet or exceed key performance benchmarks for bulk organics removal and pathogen inactivation.

Together, these findings establish the feasibility of direct ozone contact as a secondary treatment option. These systems could serve as viable options, especially in decentralized and compact treatment systems without waste activated sludge generation and for water reuse applications.