Design of an Alternative Wastewater Effluent Disinfection System

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Introduction

A municipal wastewater treatment plant (WWTP) in Nova Scotia currently uses chlorine gas to disinfect wastewater, after going through secondary physical and biological treatment processes. The treatment train is presented below in Figure 1. The WWTP is not in compliance with effluent chlorine residual limits, which have been set by the CCME[3]. Alternative disinfection methods were to be considered. The objectives of this project include determining the optimal dosage of peracetic acid (PAA) which meets regulatory standards, as well as to design the retrofitted plant which implements PAA.

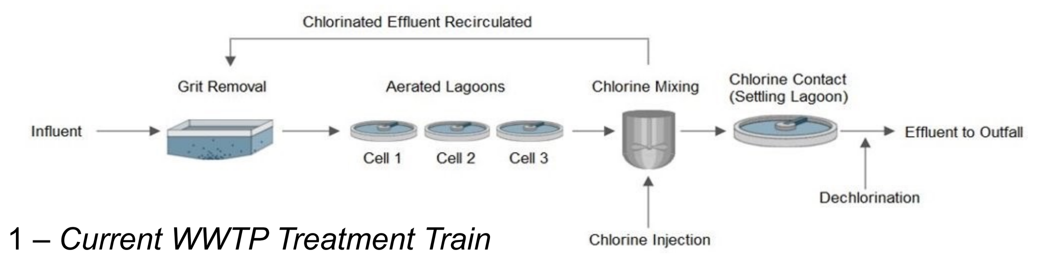

Figure 1 – Current WWTP Treatment Train

Water Quality Guidelines

Environment Canada and the CCME have set the following guidelines for effluent discharging from WWTP into the environment[3,9].

Table 1 – Canadian Wastewater Effluent Discharge Guidelines

Water Quality Parameter	Effluent Discharge Limit
pH	7-9
E. coli	200 CFU/100 mL
Residual Chlorine	0.02 mg/L
Peracetic Acid	2 mg/L

Design Process

- There are 18 full-scale PAA plants in North America[1], using dosages of 1-8 mg/L[14], regulated by effluent residual limits of 0.33-2 mg/L[14]. This information served as useful references when choosing PAA dosages for bench-scale lab testing.
- NS wastewater regulations were compared to the plant's current effluent water characteristics to identify the scope of the problem.

Table 2 – Current Effluent Water Characteristics of WWTP

Parameter	Influent	Effluent
CBOD5	300	9 mg/L
TSS	350	11 mg/L
pH	7.5	6.8
E.Coli	1500	195
Total Chlorine Residual	**-**	**0.06 mg/L**

- Alternative disinfection technologies including UV and PAA were investigated as possible replacements for chlorine gas. Evaluation criterion included cost, regulations, health and environmental risk, operator safety and sustainable design. Weights were assigned to each criterion based on the client's needs. PAA was found to be the optimal choice, and design parameters of dose, residual disinfectant and required retrofitting of the plant were determined within this project.
- A lab procedure was developed to create wastewater samples dosed at 1-8 mg/L of PAA with a contact time of 27 minutes. Residual concentrations of PAA and pH measurements were recorded using a spectrophotometer and pH probe respectively. Finally, Colilert was utilized for identifying the most probable number (MPN) of *E. Coli* and total coliforms.

Details of Design

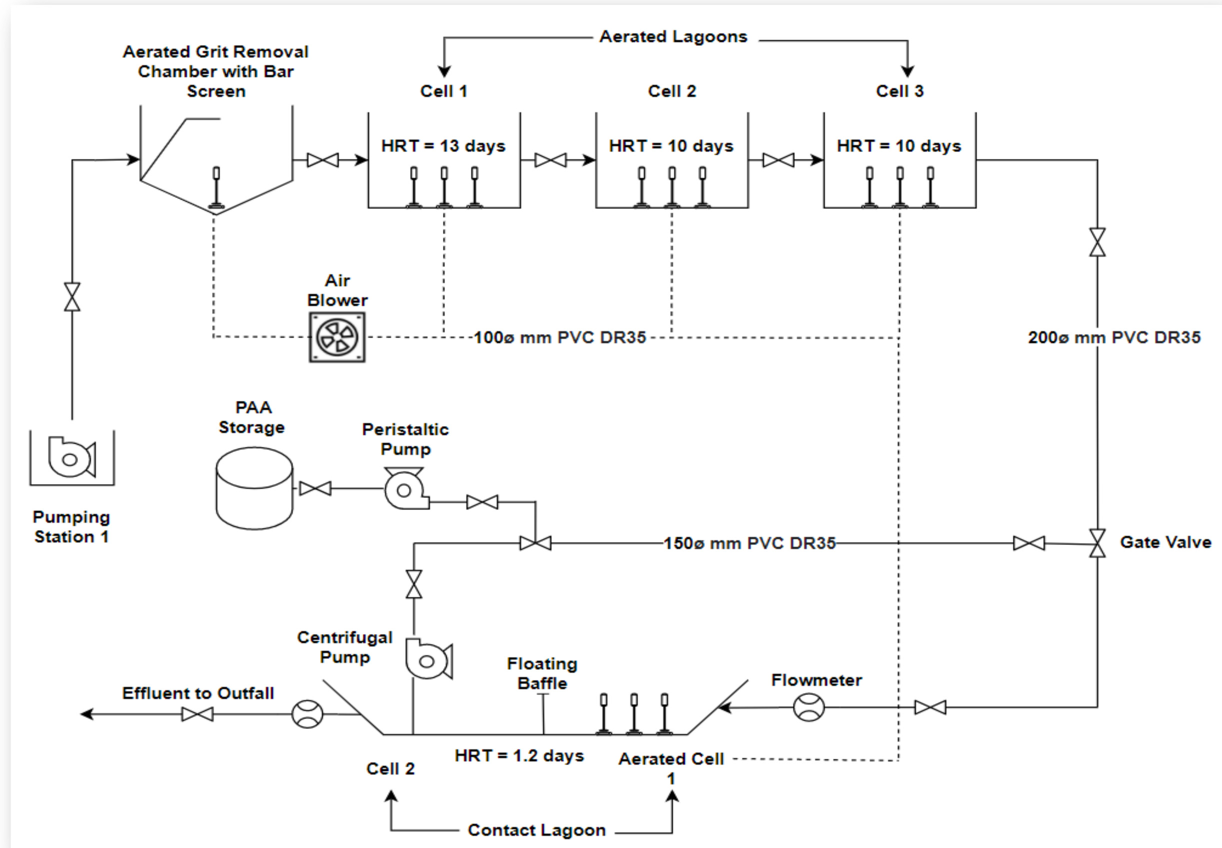

Figure 4 – Full-scale PAA WWTP Design

The retrofitted design for the WWTP is shown in Figure 4. The new implementations include a centrifugal pump which recycles water from the second cell of the contact lagoon and mixes it with PAA. The PAA dosage is controlled by a peristaltic pump as it exists from the storage tote. Lab testing determined an optimal dosage of 1 mg/L using a 15% PAA solution. Flowmeters are placed at the upstream and downstream ends of the contact lagoon to measure the flowrate, PAA concentration, and wastewater quality parameters. A final design consideration depicted in the process schematic includes isolation valves which are placed between all treatment areas in order to stop flow for maintenance.

Table 3 – Cost Analysis over 20 Year Period of PAA WWTP

Expense	Expense Type	Price	Price Units	Quantity	Monthly Cost	Purchase frequency over 20-year period	Total Cost over 20 years
qDOS 30 pump[16]	Capital	7500	$	3	22,500	2 times[6]	$45,000
Dulcotest Sensor & Dulcometer[11]	Capital	6000	$	2	12,000	4 times[4]	$48,000
Centrifugal Pump von Taine[12]	Capital	10,000	$	1	10,000	2 times[15]	$20,000
Power	Operational	0.15 [5]	cents/KWh	0.745 m³/kWh [2]	2347	240 times	$563,220
PAA[7]	Operational	3900	$/m³ WW	4.2 L/d	413	240 times	$99,206
						Total	**$775,426**

Table 4 – Retrofitting Costs

Expense for Retrofitting Plant	20 Year Cost Projection
qDOS 30 pumps[16]	$45,000
Dulcotest Sensors + Dulcometers[11]	$48,000
Centrifugal Pump[12]	$20,000
PAA	$99,206
Total 20 year projection cost	**$212,206**

Table 5 – Existing Expenses[7]

Expense for Current Plant Design	20 Year Cost Projection
Chorine gas ($0.02/m³)	$100,800
Sodium Bicarbonate ($0.036/m³)	$181,440
Total 20 year projection cost	**$282,240**

Tables 4 and 5 demonstrate a 20-year cost projection for the expenses which vary when changing the current plant design to PAA. Results demonstrate that switching to PAA will be the cheaper option over the 20-year life cycle.

Lab results display that PAA dosage has a positive correlation with residual concentrations, as shown in Figure 5, and a negative correlation with the pH, as shown in Figure 6.

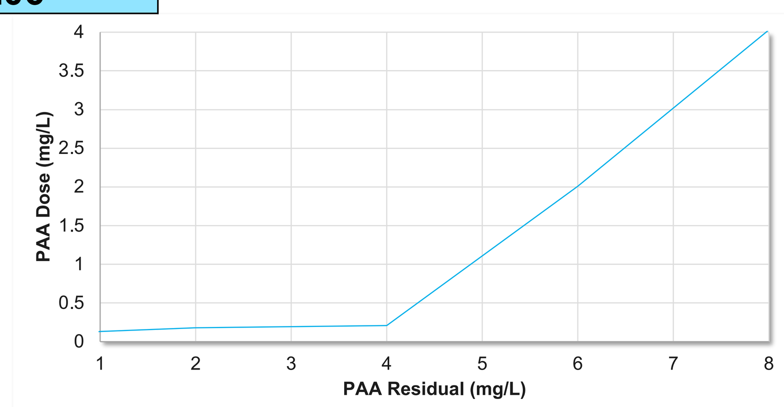

Figure 5 – Residual PAA Vs. PAA Dosage

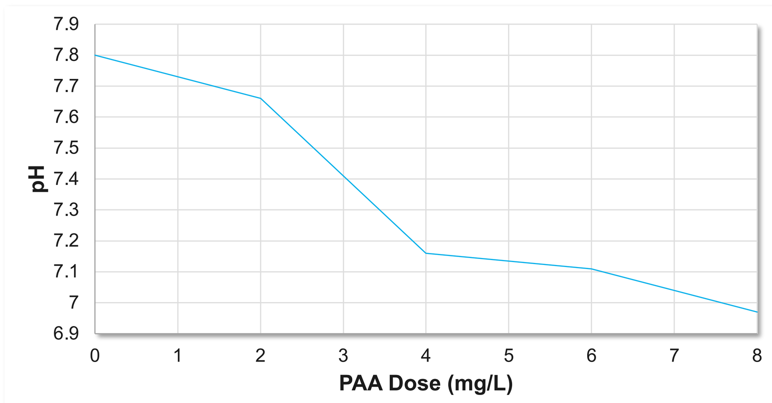

Figure 6 – pH vs. PAA Dosage

Conclusions & Recommendations

PAA was determined to be an advantageous disinfection alternative for wastewater treatment based on its pathogen removal efficacy, fast degradation kinetics, and competitive cost. A dosage of 1 mg/L was determined to be optimal, sufficiently achieving regulatory compliance. Retrofitting the plant design for PAA implementation can be achieved by replacing the existing pumps with peristaltic and centrifugal pumps respectively, as well as adding PAA sensors.

Future Work Recommendations for Full-Scale Plant Implementation

- Plate counts additionally to Colilert (more specific)
- Trial repeats (kinetics testing)
- Dose testing for various flow conditions (high flow vs. low flow)
- Gain approval (LC50 test for fish toxicity)
- Pilot plant implementation

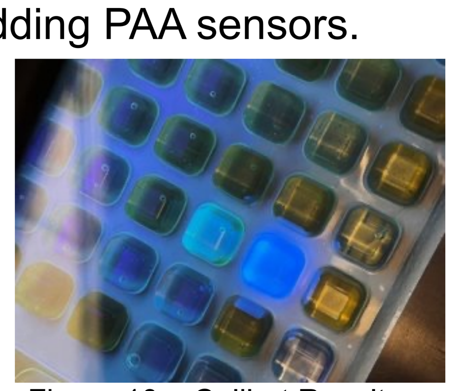

Figure 10 – Colilert Results

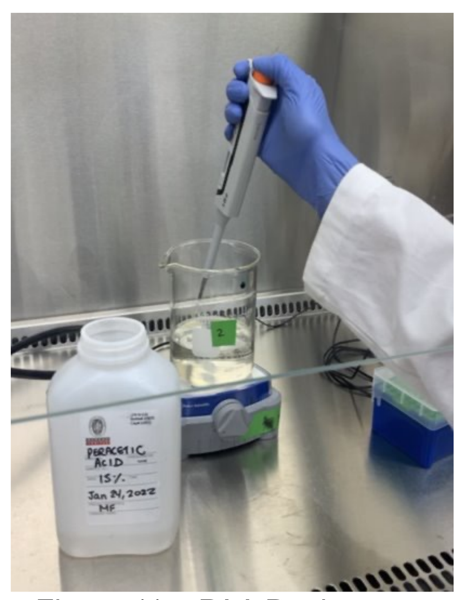

Figure 11 – PAA Dosing

Disinfection Kinetics

The decay rate of PAA in wastewater was identified by taking residual measurements at 0, 5, 12, 20 and 25-minute contact times.

Testing determined a first order decay rate of 0.084 min^{-1} for a 1 mg/L dosage of PAA at 20 °C, as displayed by Figure 7. Literature values suggest a similar decay constant of 0.087 m^{-1} under the same conditions[13].

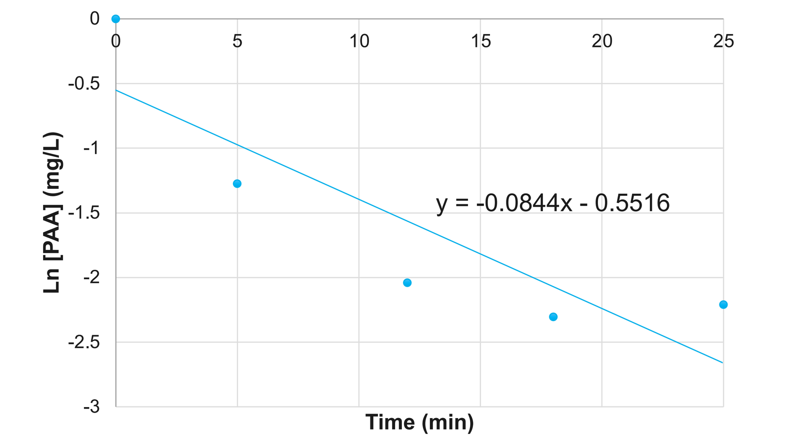

Figure 7 – Kinetics of PAA in wastewater (1 mg/L dose)

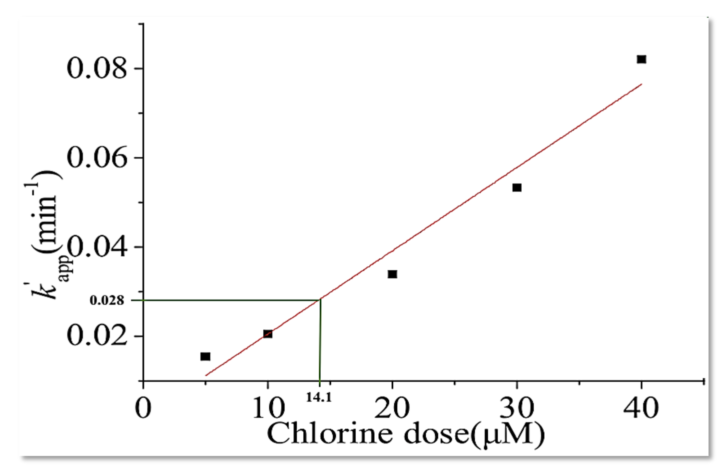

Figure 8 - Kinetics in Chlorine in Wastewater [17]

First order decay rates of chlorine in wastewater were estimated to be 0.028 min^{-1} [17]. Comparing the degradation kinetics of the two disinfectants supports that PAA degrades considerably faster than chlorine, which is susceptible to having residual values above the Nova Scotia regulations.

Chick's Rate Law can be used to determine degradation rate constants from the slope of the lines presented in Figures 7 and 8. The Chick's Law relationship is presented in Figure 9.

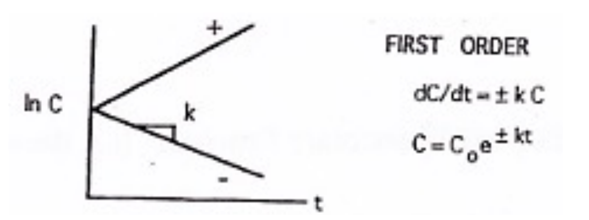

Figure 9 – Chick's Law [8]

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