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Disinfection Pilot Trial for Little Miami WWTP

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Disinfection Pilot Trial for Little Miami WWTP

by

Project Team:

Dr. Achal Garg, Metropolitan Sewer District of Greater Cincinnati MSD, was the project leader and supervised the planning and execution of the experiments.

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Dr. Kwok-Keung Au, PeroxyChem, participated in the planning and execution of the study, data analysis and provided support to prepare the final report.

Disclaimer

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Executive Summary

Peracetic acid (PAA) was shown to provide effective bacterial reduction during field pilot trialing at the Little Miami Wastewater Treatment Plant, located in Cincinnati, OH. Reduction of both fecal coliform and *E. coli* to below the permitted requirements was demonstrated even at low PAA doses.

Key findings:

- A PAA dose rate of **1.0 mg/L** and a contact time of 30 minutes were sufficient to achieve the disinfection goal to reduce the geometric mean of fecal coliform to below 200CFU/100 mL, which is the current permit limit value for April to October. The same dose rate and contact time were able to reduce the geometric mean of *E. coli* to below 126 CFU/100 mL.

- A PAA dose rate of **0.5 mg/L** and a contact time of 30 minutes were sufficient to achieve the disinfection goal to reduce the geometric mean of fecal coliform to below 1,000 CFU/100 mL, which is the current permit limit value for November to March.

- At the effective doses of 1.0 mg/L and 0.5 mg/L, the residual PAA concentration at the effluent discharge was always below 1.0 mg/L. As a result, it is anticipated there will be no requirement to quench residual PAA prior to discharge, although the Ohio Environmental Protection Agency (OEPA) has not yet set a specific discharge limit.

- Whole Effluent Toxicity (WET) testing for composited samples, collected at PAA dose concentration of 1.0 and 2.0 mg / L, resulted in “passing” performance, with values for the TUa (acute toxicity unit) below detection for all the samples tested.

Proposed Next Steps:

Given the success of PAA in achieving the target microbial reductions, it is recommended that a full-scale field trial be conducted within the plants’ disinfection contact chambers to assess long-term performance under water quality and hydraulic flow conditions experienced at the site.

This report and the conclusions herein are based on the data generated from the field pilot test conducted at the Little Miami Wastewater Treatment Plant.

I. Introduction

Disinfecting wastewater effluent is a critical final step in the treatment of wastewater. It protects public health and the environment by inactivating disease-causing organisms such as bacteria, viruses, and parasites. Various methods and technologies are used to accomplish the goal of effluent disinfection. These include ultraviolet (UV) irradiation (Carmineo et al., 1994; Lazarova et al., 1998; Kolch, 2000), ozone treatment (Lazarova et al., 1998; Andreottola et al., 1996), and use of various chlorine derivatives (Hajenian & Butler, 1980; Zanetti et al., 1996; Legnani et al., 1996). In the USA, wastewater effluent is mainly disinfected by chlorine derivatives because of their wide spectrum of disinfection efficiency and low treatment cost. Recent research, however, has evoked concerns about effluent chlorination promoting the formation of toxic, mutagenic, and carcinogenic properties in its disinfection by-products (DBPs). These harmful DBPs increase the toxicity of the effluent that is discharged into water bodies with potential to cause harm to the water quality and the environment (Dell'Erba et al. 2007; Kauppinen et al. 2012; Veschetti et al. 2003).

Peracetic acid (PAA) is a strong oxidizing organic compound with a wide spectrum of antimicrobial/biocidal properties similar to liquid chlorine or sodium hypochlorite (NaOCl). It has been widely used in the food, beverage, medical, and pharmaceutical industries for over 20 years (Kitis, 2004). Because of its strong antimicrobial properties, PAA has been getting a lot of attention as a wastewater disinfectant to replace chlorine in recent years (Lefevre et al., 1992; Baldry et al., 1995; Sanchez-Ruiz et al., 1996; Stampi et al., 2001, 2002; Wagner et al., 2002). It has been reported that PAA and sodium hypochlorite have similar antimicrobial activities against E. coli, fecal coliform, and total coliform (Veschetti et al., 2003); however, PAA holds multiple advantages over sodium hypochlorite as disinfectant for wastewater effluent. These advantages include: need for lower doses, lower residuals, faster disintegration, and absence of disinfection byproducts (DPBs) in the treated effluent (Booth and Lester, 1995; Liberti and Notarnicola, 1999; Monarca et al., 2000; Kitis 2004; Vaschetti et al., 2003; Crebelli et al., 2005; Koivunen & Heinonen-Tanski, 2005; Antonelli et al., 2013).

The purpose of this study was to compare PAA and NaOCl disinfection efficiencies on the secondary effluent in the lab and in a pilot study at the Little Miami Treatment Plant (LMTP) in Cincinnati, Ohio. The study was comprised of a series of lab experiments to target fecal coliform and *E. coli* followed by a sidestream pilot scale study with the following goals: (1) evaluate the

suitability of PAA as a wastewater disinfectant for secondary effluent by measuring the inactivation efficiency against target organisms, (2) determine the dose and contact time necessary to keep the LMTP in compliance with the National Pollution Discharge Elimination System (NPDES) requirements for fecal coliform and E. coli discharge limits, and (3) assess the rate of PAA degradation by measuring residual PAA in wastewater.

1.1 Objectives:

A pilot disinfection trial was conducted at the Little Miami Wastewater Treatment Plant (WWTP) in Cincinnati, OH. The objectives of this trial were:

- To study the effectiveness of peracetic acid (PAA) to achieve compliance with the wastewater discharges permit disinfection criteria for microbial indicators, fecal coliform, and *E. coli.*
- To determine the operating conditions (PAA dose and contact time) required to achieve such requirements.
- To assess the impact of PAA on the aquatic toxicity of the wastewater effluent.

The Little Miami Plant's current National Pollutant Discharge Elimination System (NPDES) permit has requirements for fecal coliform not to exceed 200 CFU/100 mL (monthly geometric mean) for April to October and not to exceed 1,000 CFU/100 mL (monthly geometric mean) for November to March. These limit values were used as the criteria to determine the target PAA dose rate and contact time required for success during this trial. In addition, the disinfection performance against another microbial indicator, *E. coli*, was studied in this trial. A limit value of 126 CFU/100 mL for *E. coli* was used as the disinfection goal in this study. Note that a geometric mean of 126 CFU/100 mL is a typical permit limit requirement in other States that use *E. coli* as the indicator microbe in their NPDES permit.

1.2 Peracetic Acid:

PAA is a strong disinfectant that results from the equilibrium reaction between acetic acid (vinegar) and hydrogen peroxide (H_2O_2). The PAA solution used in this study contains 15% peracetic acid (PAA) and 23% hydrogen peroxide (see Figure 1-1 for the chemical structure). The PAA molecule attacks and kills microbial organisms of concern in wastewater treatment, such as fecal coliforms and *E. coli* by disruption of cell membranes.

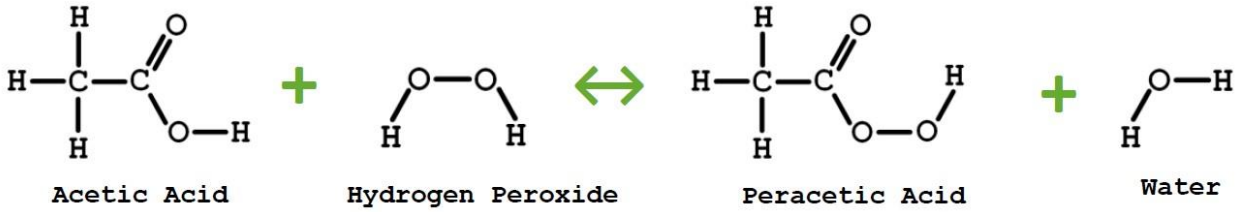

Figure 1-1 Chemical Structure of PAA

The oxidation potential of PAA is greater than that of hypochlorous acid, hypochlorite ion and monochloramine (shown in Table 1-1), resulting in typically lower dosages and contact times as compared to using chlorine or chloramines. In addition, PAA has a much lower aquatic toxicity profile than chlorine and decays rapidly in the environment. As a result, PAA generally does not need a quenching step, such as dechlorination, reducing process complexity and cost. PAA is not a chlorine-based chemistry and does not result in the formation of chlorinated disinfection by-products such as trihalomethanes (THMs), and other byproducts such as cyanide and n-Nitrosodimethylamine (NDMA).

Table 1-1 Standard Oxidation Potential (Kitis, 2004)

Oxidant	Standard Potential (V)
PAA (CH_3COOOH)	1
Hyporchlorous Acid (HOCl)	1
Monochloramine (NH_2Cl)	1
Hypochlorite Ion (OCl^-)	0

2. Test Plan: Lab Studies:

2.1 Materials:

The effluent samples were collected from the Little Miami wastewater treatment plant owned by the Metropolitan Sewer District of Greater Cincinnati (MSD), Ohio, USA. Peracetic acid (15%), marketed under the commercial name of VigorOX WWT II, was supplied by PeroxyChem, Philadelphia, USA. PVS Chemical Solutions, Chicago, USA, supplied sodium hypochlorite (NaOCl) (12%). E. coli and fecal coliform broth were obtained from Hach. Buffered water with magnesium, micro filters, sampling bottles, and microbiological petri dishes were from Thermo Fisher Scientific, Pittsburg, USA.

2.2 Methods:

Bench Study Experimental Set-Up

Grab samples of secondary effluents were collected to compare the disinfection efficiency of PAA and NaOCl in the lab study. Samples of non-chlorinated raw effluent were collected in sterile 100 milliliter plastic bottles and analyzed for fecal coliform and E. coli within 6 hours of collection. To investigate the disinfection efficiency, the samples were treated with 2 to 7 ppm doses of NaOCl or PAA for 10, 15, and 20 minutes. Membrane filtration method was used to measure the efficiency of the treatment (Standard Methods, 22nd Ed., American Public Health Association).

3. Test Plan: Pilot Study:

The PeroxyChem disinfection pilot reactor (DPR, Fig 3-1) was used in this pilot study. Non-disinfected wastewater is fed into the DPR via a submersible pump, typically situated within the effluent weir of the secondary clarifier. The flow rate through the DPR can be adjusted to a maximum of 30 gallons per minute(gpm), and the effluent is discharged back to the plant process stream prior to the final disinfection stage. A series of sampling ports are located along the reaction section of the DPR. The combination of flow rate through the DPR and selection of the sampling port allows for a wide range of contact times to be simulated. PAA dosage at the head of the DPR is controlled via a metering pump to achieve the desired target PAA dose concentration. As a result, microbial reduction, PAA usage and water quality impacts can be assessed in the actual plant wastewater under a variety of initial PAA dose concentrations and contact times.

Pilot Study Experimental Set-Up

The pilot study was conducted at the Little Miami Treatment Plant (LMTP) operated by the Metropolitan Sewer District of Greater Cincinnati (MSD), Ohio. It is a secondary treatment facility with an average flow of 25 million gallons per day (MGD).

Fig 3-1: Disinfection Pilot Reactor (DPR).

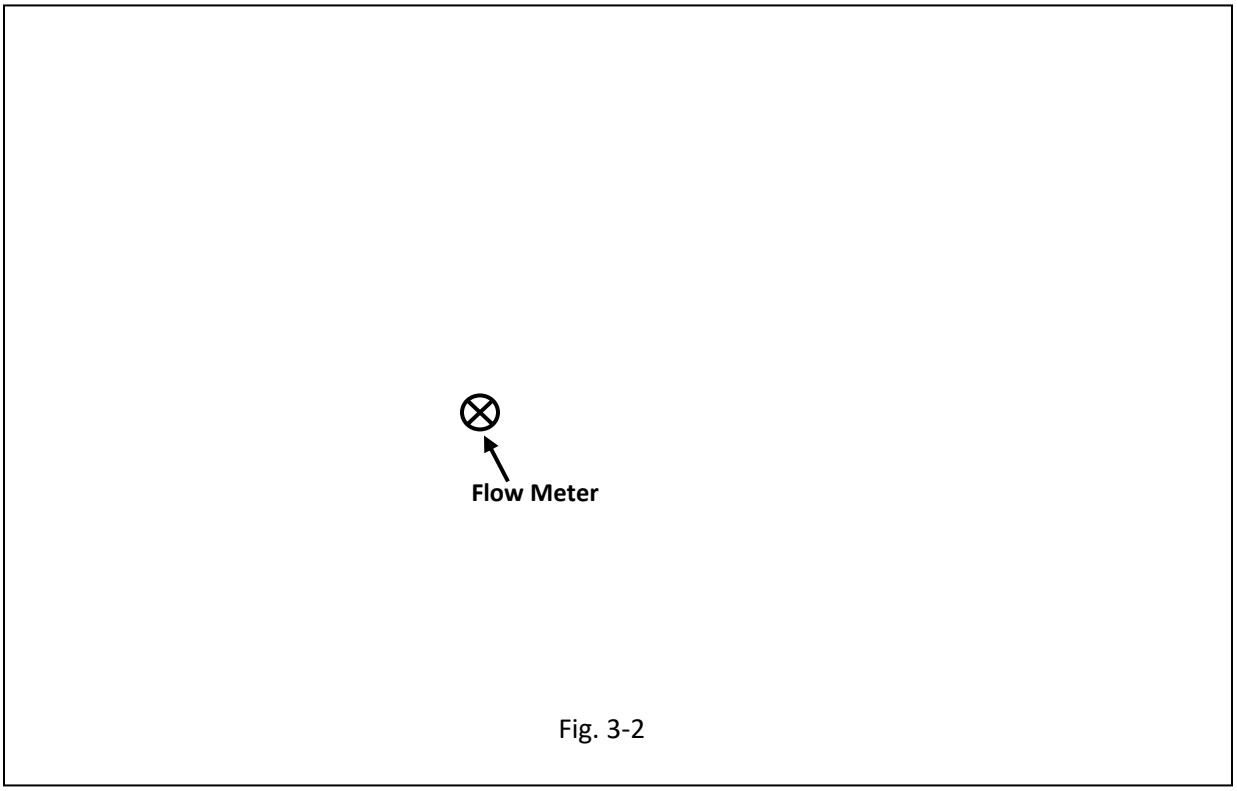

Fig. 3-2

The pilot study was conducted on a Disinfection Pilot Reactor (DPR) (Fig. 1) owned and supplied by PeroxyChem. The non-chlorinated secondary effluent was pumped into the reactor through a submersible water pump. The effluent flow rate to the reactor was controlled using three flow control valves (V1-V3). The flow rate was maintained at 15 gallons per minute (gpm) throughout the period of the pilot study. The untreated control effluent sample was collected at sample collection port (R1) downstream of PAA injection point. A PAA injection point (S1) was located upstream of the flow meter and downstream of PAA treated sample collection ports (P1-P6).

3.1 Trial Schedule

Data and sample collection of the PAA DPR field trial were started on June 6 and ended on September 10, 2016. During this period, the DPR was completely operated by the LMTP plant staff, which performed sample collection. All sample analyses were performed by the Plant staff or laboratories selected by the Plant staff. Results were provided to PeroxyChem on a routine basis. Close communication between Plant staff and PeroxyChem staff was maintained during the trial period.

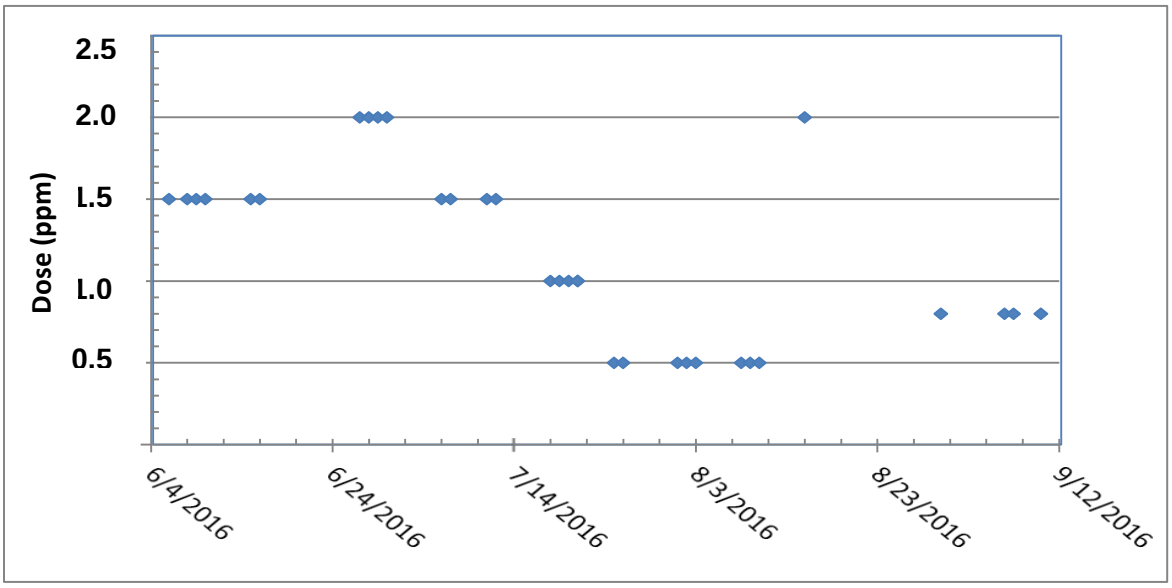

Figure 3-3 PAA Testing Dose during the Trial Period

3.2 Testing Flow Rate and PAA Dose

Non-disinfected secondary effluent was pumped into the DPR at a constant flow rate of 15 gpm during the sampling/data collection period. The PAA dose concentrations used during the data/sample collection period is shown in Figure 3-3 and varied from 0.5 mg/L to 2.0 mg/L. The dose rate was adjusted as needed, mainly based on monitored results of fecal coliform and *E. coli* in the final effluent. During the trial period, the Plant staff and PeroxyChem staff reviewed testing data at least weekly and made necessary adjustment for the PAA dosing rate.

3.3 Microbiological Analysis:

The effluent samples for microbial analysis were collected in 100 ml sterile plastic bottles containing 10 mg sodium thiosulfate (Thermo Fisher Scientific, Cat# 05-719-361) for neutralizing any residual PAA and H_2O_2 instantaneously. Each analysis was carried out on fecal coliform and E. coli using a membrane filter. The fecal coliform colonies were counted after incubation for 24 ± 2 hours in a 44.5 ± 0.2ºC water bath. *E. coli* plates were incubated for the same time in a 35 ± 0.5ºC water bath (Standard Methods, 22nd Ed.).

3.4 Water Quality Monitoring:

The water quality monitoring plan is shown in Table 3-1 below.

Table 3-1 Water Quality Monitoring Plan for Little Miami WWTP DPR Trial

Water Quality Parameters	Sampling Location				Sampling Frequency	Sampling Type
	Influent (upstream of VigorOx Feeding Point	Sampling Port #3[(2)]	Sampling Port #4[(2)]	Sampling Port #6[(2)] (final effluent)		
Fecal Coliform (MPN/100 mL)	√	√	√	√	Twice a Day	Grab
E. coli (CFU/100 mL)	√	√	√	√	Twice a Day	Grab
PAA Residual[(3)]	NA	√	√	√	Twice a Day	Grab
Hydrogen Peroxide[(4)]	NA	√	√	√	Twice a Day	Grab
Chloride (mg/L)	√	NA	NA	NA	Twice a Day	Grab
Dissolved Oxygen (mg/L)	√	NA	NA	√	Once a Day	Grab
Ammonia (mg/L as N)	√	NA	NA	√	Once a Day	Grab
TSS (mg/L)	√	NA	NA	√	Weekly	Grab
$cBOD_5$ (mg/L)	√	NA	NA	√	Weekly	Grab
pH	√	NA	NA	√	Twice a Day	Grab
Water Temperature (C)	√	NA	NA	NA	Twice a Day	Grab
Whole Effluent Toxicity	NA	NA	NA	√	Once during the Trial	In accordance to permit

Methodology:

(1) All samples were collected and measured by Plant staff or a laboratory selected by Plant. Grab samples for different measurements were taken at the same time.

(2) At the test flow rate of 15 gpm, the corresponding contact time at port #3, #4 and #6 were 9 minutes, 17 minutes, and 30 minutes.

(3) PAA residual was measured using CHEMetrics V-2000 method. PeroxyChem provided a handheld unit and associated training.

(4) Hydrogen peroxide was measured using a CHEMetrics I-2016 Peroxide SAM unit. PeroxyChem provided a handheld unit and associated training.

(5) Sampling bottles for fecal coliform and *E. coli* contained quenching agent to neutralize any oxidant residual in the samples.

(6) Dilution of *E. coli* and fecal coliform samples was done as needed to obtain the exact microbial count number.

(7) There was a minimum time gap of 3 hours between daily AM and PM samples. Every time the test dose was changed, there was a minimum time gap wait of 2 hours before any sample

was taken.

4. Results and Discussions

4.1 **Benchtop Lab Studies:** Both lab studies and pilot project study show that PAA is as effective as sodium hypochlorite (NaOCl) in disinfecting wastewater effluent. The bench top studies were conducted in the lab as a precursor to the pilot study. The PAA efficiency was compared with sodium hypochlorite at different doses and contact times on fecal coliform and E. coli as target microorganisms. The microbial inactivation efficiency of both disinfectants was measured between a 3 and 7 mg/L range. PAA was found to be significantly more effective at lower doses of 3 and 4 mg/L concentrations compared to NaOCl. From 5 to 7 mg/L concentrations, the difference between PAA and NaOCl efficiency was insignificant and showed similar disinfection against fecal coliform and E. coli after 10, 15, or 20 min contact times. The optimal microbial inactivation was achieved at 6 mg/L with PAA and NaOCl achieving between 4.5 and 5 log reduction. No additional bacterial inactivation was achieved by increasing the doses to 7 ppm (Fig. 4-1).

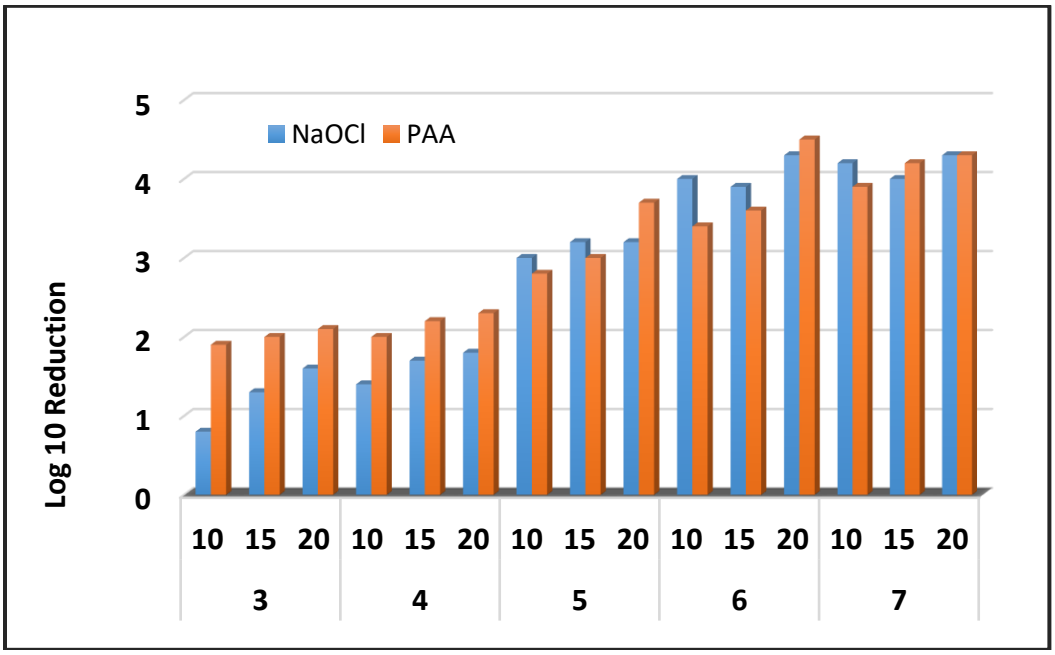

Fig. 4.1 Benchtop Study: Comparison of NaOCl and PAA Efficiencies on E. coli in Secondary Effluent

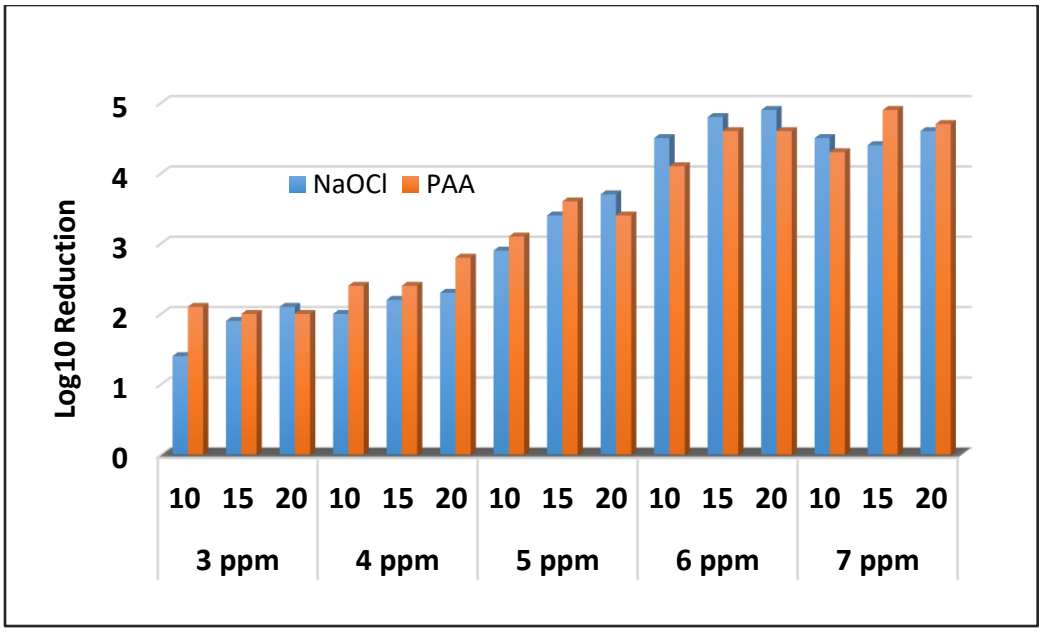

Fig. 4.2 Benchtop Study: Comparison of NaOCl and PAA Efficiencies on Fecal coliform in Secondary Effluent

4.2 Side-stream PAA Disinfection Pilot Study: The disinfection efficiency of PAA against E. coli and fecal coliform in the pilot project was dependent on the dose and the length of contact time. Fecal coliforms were found to be more sensitive to the PAA's effect than E. coli. At PAA concentrations of 1.3 mg/L and 1.5 mg/L, a 1 log reduction was achieved on fecal coliform after a 9min contact time. In comparison, only a 0.5 to 0.8 log reduction was observed in the number of E. coli bacteria when exposed to 1.3 to 1.5 mg/L for 9 min contact time. The 2 mg/L concentration was significantly effective against fecal coliform at 9 min showing a 1.8 log reduction in fecal coliform compared with 1.3 and 1.5 mg/L for the same contact time. The highest fecal coliform inactivation of 2.5 log reduction, was achieved at 30 min with 2 mg/L concentration (Fig. 4.3) As for E. coli, there was a 1.8 to 2.3 log reduction depending on the PAA concentrations (Fig 4.4).

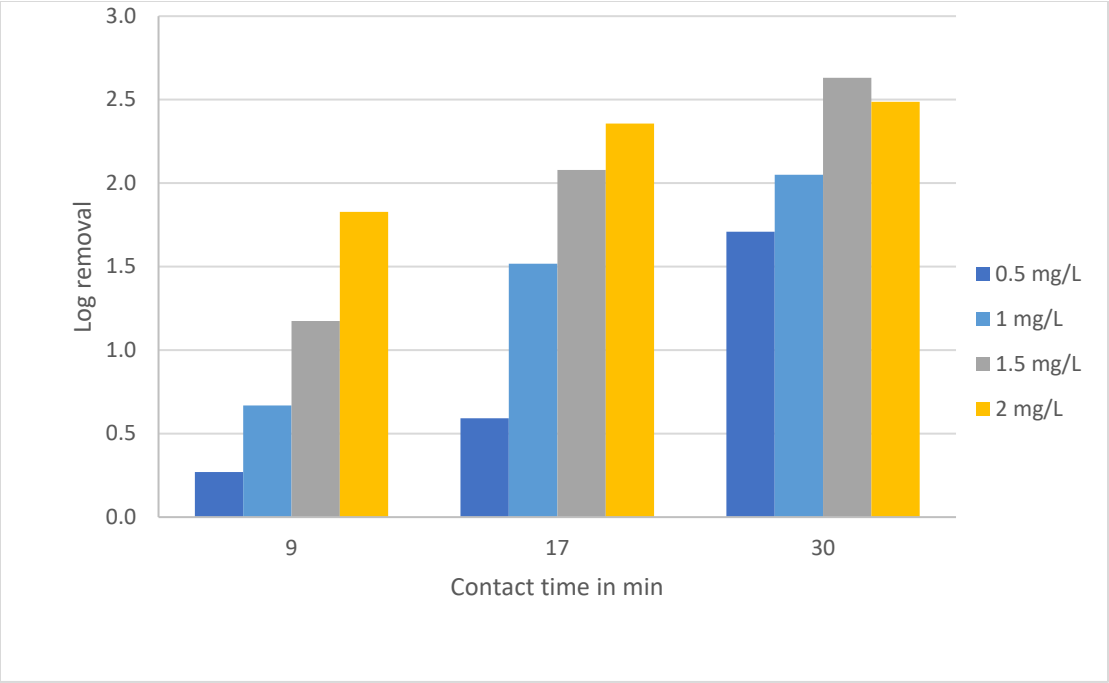

Fig. 4-3 Log removal vs. Contact time with PAA in the pilot study: Fecal

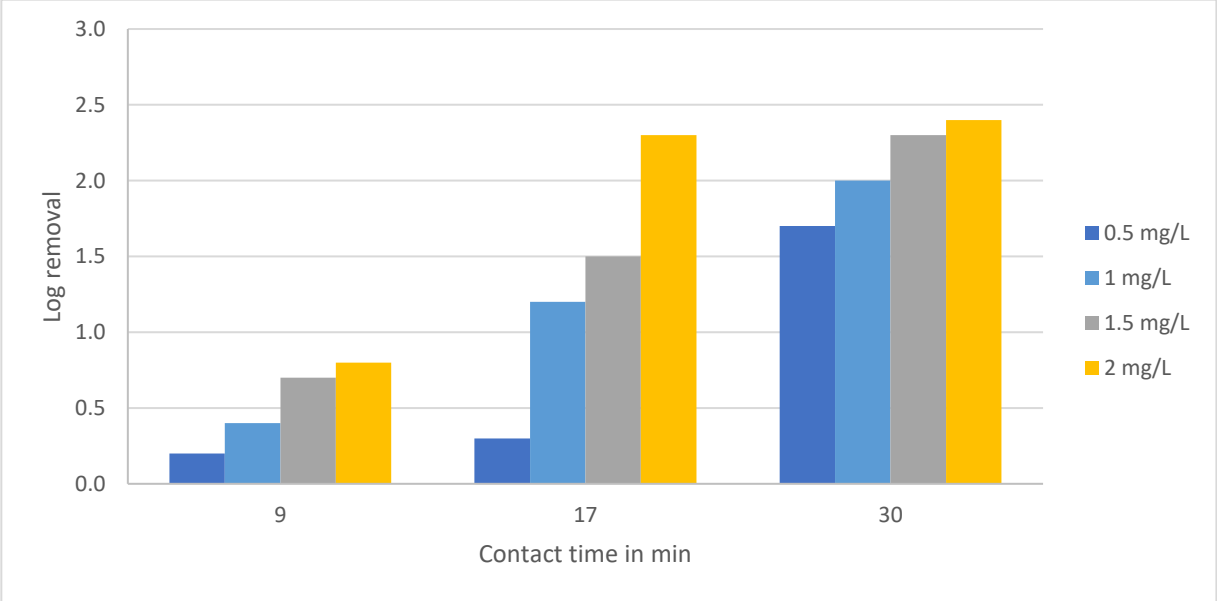

Fig. 4-3 Log removal vs. Contact time with PAA in the pilot study:

4.3 Influent Fecal Coliform and *E. coli* Concentrations

The fecal coliform and *E. coli* concentrations in the non-disinfected influent to the DPR during the trial period are shown in Figure 4-5 and Figure 4-6, respectively. The horizontal green and red lines in Figure 4-5 represent the seasonal permit limit values of fecal coliform of 200 CFU/100 mL and 1,000 CFU/100 mL, respectively. The horizontal red line in Figure 4-6 represents

the potential permit limit value of *E. coli* of 126 CFU/100 mL.

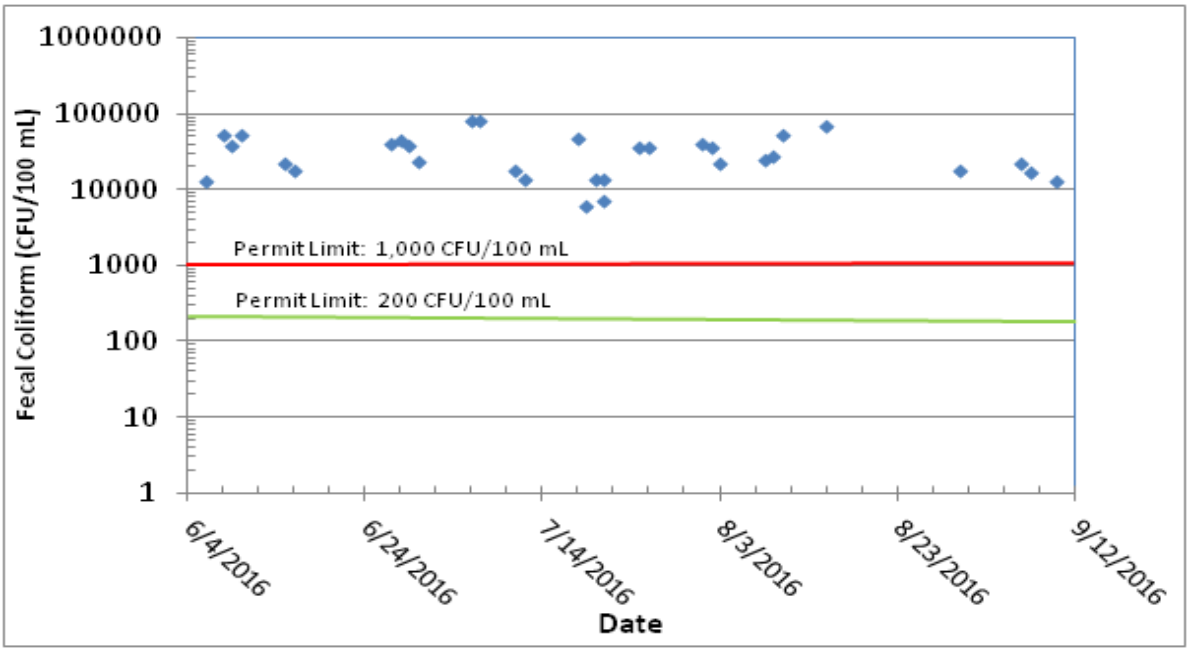

Figure 4-5 Fecal Coliform Concentrations in Non-Disinfected Influent to DPR during Trial Period.

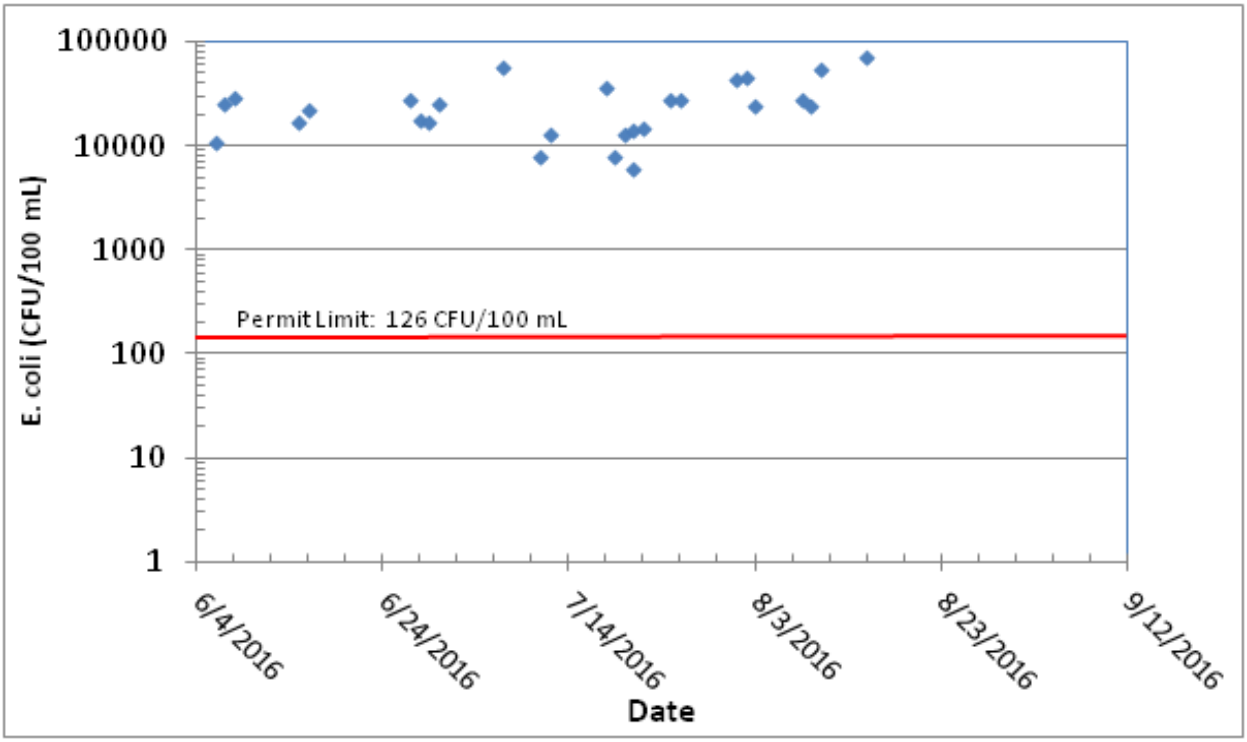

Figure 4-6 *E. coli* Concentrations in Non-Disinfected Influent to DPR during Trial Period

The non-disinfected influent fecal coliform concentrations varied from 6,000 CFU/100 mL to 230,000 CFU/100 mL, with a geometric mean of 29,933 CFU/100 mL. The non-disinfected influent

E. coli concentrations varied from 6,000 CFU/100 mL to 72,000 CFU/100 mL, with a geometric mean of 22,191 CFU/100 mL.

Based on the non-disinfected influent fecal coliform levels, the log reductions required to reduce fecal coliform concentrations to 200 CFU/mL and 1,000 CFU/100 mL were calculated. The results are displayed in Figure 4-7. Similarly, the log reduction required to reduce *E. coli* concentrations to 126 CFU/100 mL was calculated and shown in Figure 4-8.

The results demonstrated that, depending on the influent concentration, a reduction from 1.48 logs (96.70%) to 3.06 logs (99.91%) was required to reduce fecal coliform to 200 CFU/100 mL during the trial period, based on single measurement. A reduction from 0.78 logs (83.50%) to 2.36 logs (99.56%) was required to reduce fecal coliform to 1,000 CFU/100 mL, based on single measurement. Similarly, a reduction from 1.68 logs (97.90%) to 2.76 logs (99.83%) was required to reduce *E. coli* to 126 CFU/100 mL, based on single measurement.

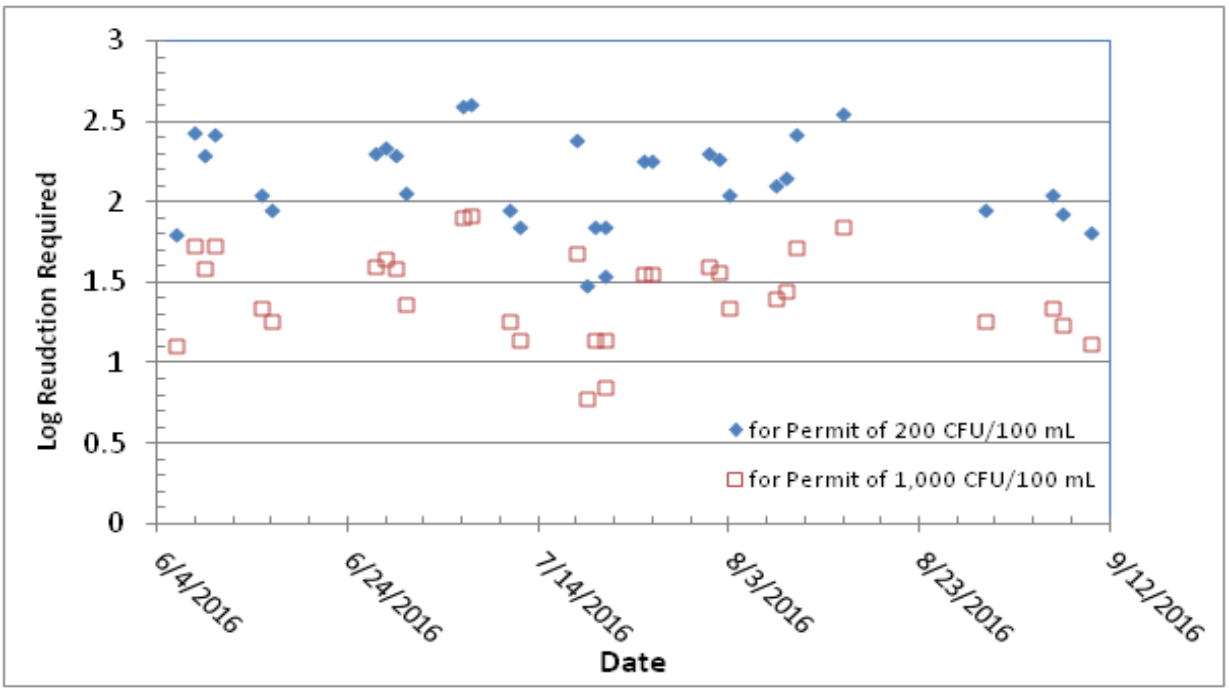

Figure 4-7: Log Reductions Required to Inactivate Fecal Coliform to 200 CFU/100 mL and 1,000 CFU/100 mL.

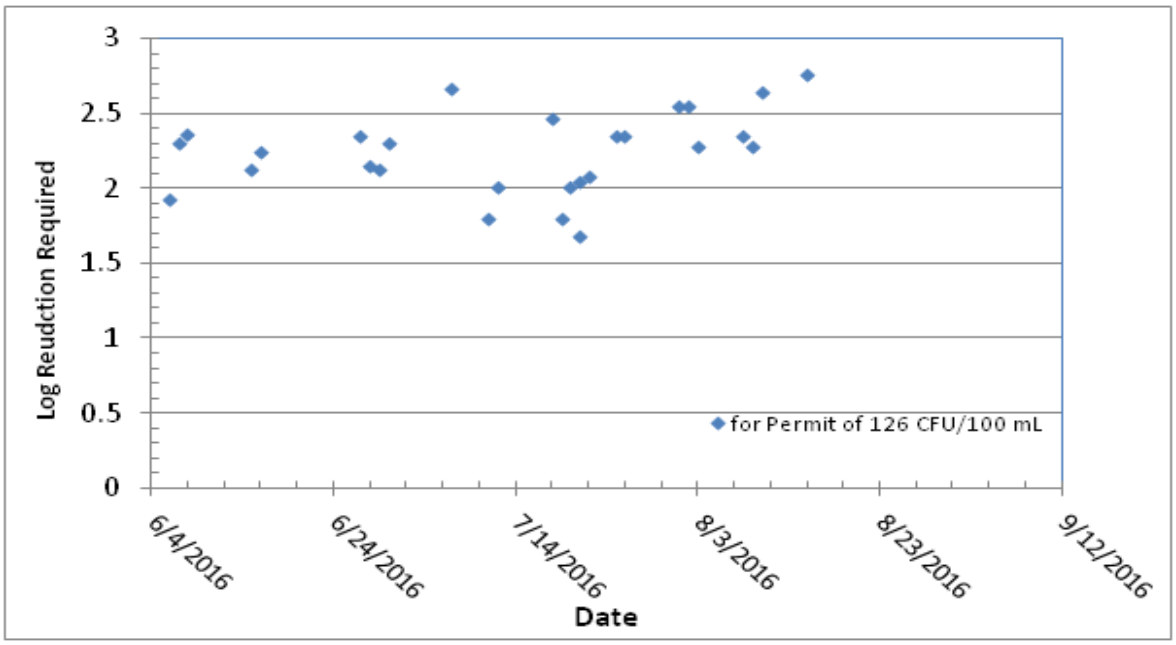

Figure 4-8 Log Reductions Required to Inactivate *E. coli* to 126 CFU/100 mL.

4.4 Disinfection Performance against Fecal Coliform

The disinfection performance against fecal coliform during the pilot trial is described in this section. The fecal coliform concentrations measured at the influent and effluent of the DPR at contact times of 30, 17 and 9 minutes are shown in Figure 4-9 (contact time 30 minutes), Figure 4-10 (contact time 17 minutes) and Figure 4-11 (contact time 9 minutes). Note that 30 minutes represents the contact time for the plant's contact chamber at average flow rate. 17 minutes represents the contact time for the plant's peak flow condition. In addition, included in these figures are the seasonal permit limit values of fecal coliform. The vertical dashed lines in the figures are drawn to separate the data set into groups, each with a specific constant PAA dose concentration. A statistical summary of the effluent concentrations at different contact times under various PAA doses is illustrated in Table 4-1.

The results demonstrated excellent PAA disinfection performance:

- As expected, the fecal coliform concentrations in the effluent generally decreased with increasing PAA dose and increasing contact time.
- A PAA dose rate of **1.0 mg/L** and a contact time of 30 minutes were sufficient to achieve the disinfection goal to reduce the geometric mean of fecal coliform to below 200 CFU/100 mL, which is the current permit limit value for April to October.
- A PAA dose rate of **0.5 mg/L** and a contact time of 30 minutes were sufficient to achieve the disinfection goal to reduce the geometric mean of fecal coliform to below 1,000

CFU/100 mL, which is the current permit limit value for November to March.

- For peak flow condition (contact time of 17 minutes), a PAA dose of 2.0 mg/L was required to reduce the geometric mean of fecal coliform to below 200 CFU/100 mL. A PAA dose of 1.0 mg/L was required to reduce the geometric mean of fecal coliform to below 1,000 CFU/100 mL for peak flow condition.

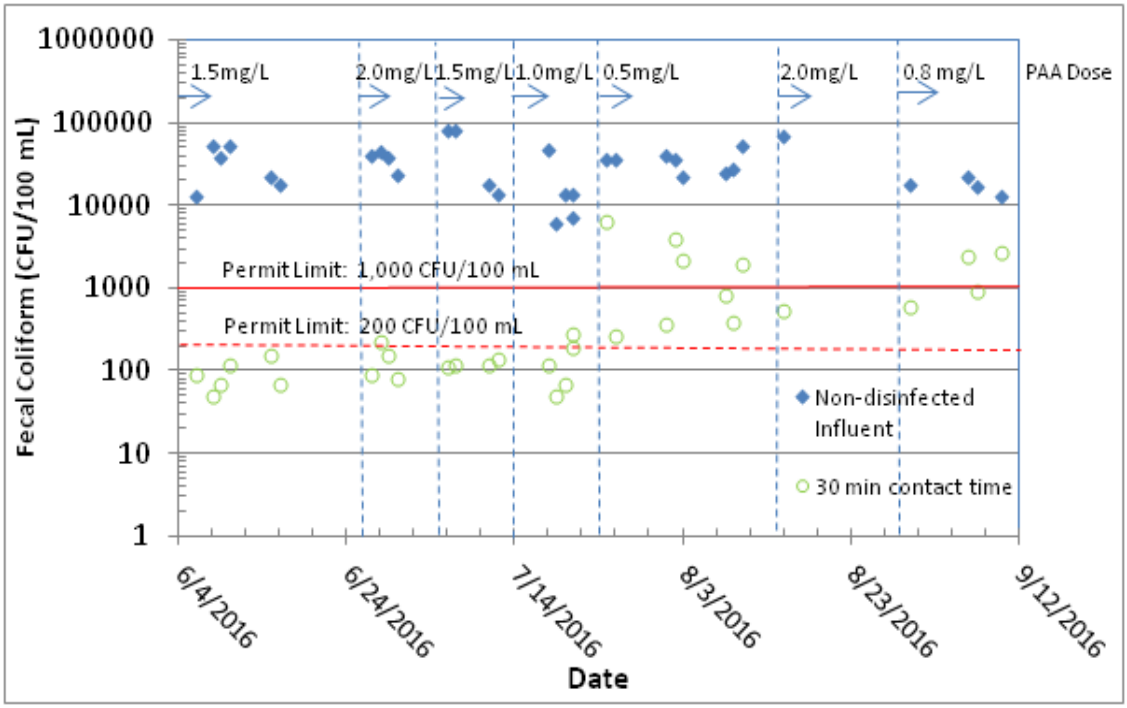

Figure 4.9 Fecal Coliform Concentrations at a contact time of 30 minutes.

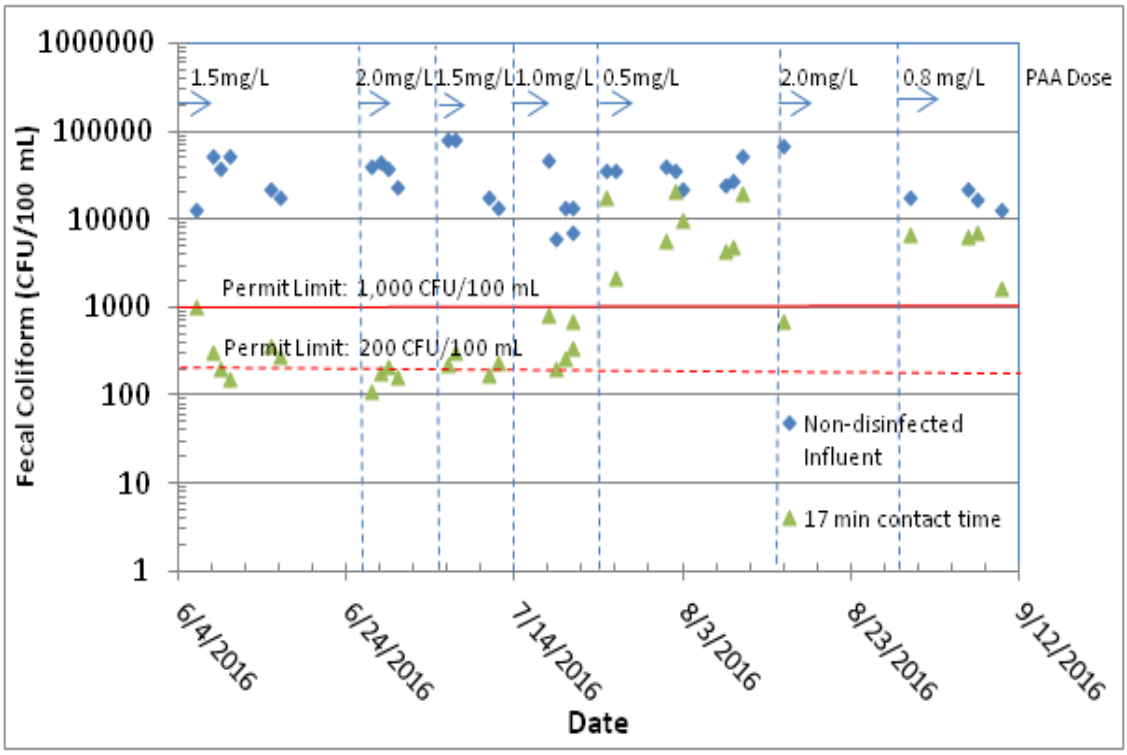

Figure 4-10 Fecal Coliform Concentrations at a contact time of 17 minutes.

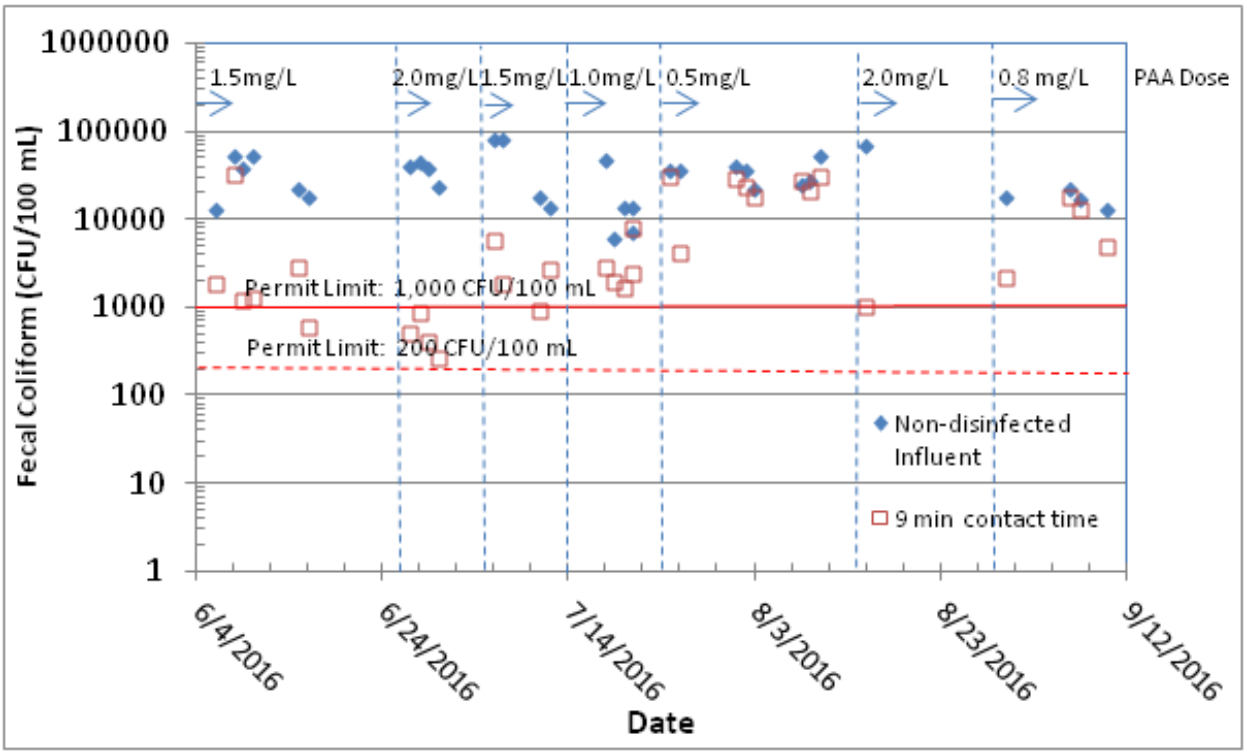

Figure 4-11 Fecal Coliform Concentrations at a contact time of 9 minutes.

Table 4-1 Statistical Summary of Fecal Coliform Concentrations

Contact Time in Minutes	*Fecal Coliform at various PAA doses at different sampling locations In CFU/100 mL (geomean)*					Fecal Coliform Permit Limits in CFU/100 mL (geomean)	
	0.5 mg PAA/L	0.8 mg PAA/L	1.0 mg PAA/L	1.5 mg PAA/L	2.0 mg PAA/L	April to October	Nov to March
30	**633**	1,368	**117**	112	102	**200**	**1,000**
17	8,458	4,805	400	324	137		
9	19,194	7,123	2,818	2,314	464		

Geomean vales were calculated based on the available data, rather than 30-day or 7-day results.

4-5 Disinfection Performance against *E. coli*

The disinfection performance against *E. coli* during the pilot trial is described in this section. The *E. coli* concentrations measured at the influent and effluent of the DPR at contact times of 30, 17 and 9 minutes are shown in Figure 4-12 (contact time 30 minutes), Figure 4-13 (contact time 17 minutes) and Figure 4-14 (contact time 9 minutes). A statistical summary of the effluent *E. coli* concentrations at different contact times under various PAA doses is illustrated in Table 4-2. The results, once again, demonstrated excellent PAA disinfection performance:

- As expected, the *E. coli* concentrations in the effluent decreased with increasing PAA dose and increasing contact time.
- A PAA dose rate of **1.0 mg/L** and a contact time of 30 minutes were sufficient to achieve the disinfection goal to reduce the geometric mean of *E. coli* to below 126 CFU/100 mL.
- For peak flow condition (contact time of 17 minutes), a PAA dose of 2.0 mg/L was required to reduce the geometric mean of *E. coli* to below 126 CFU/100 mL.

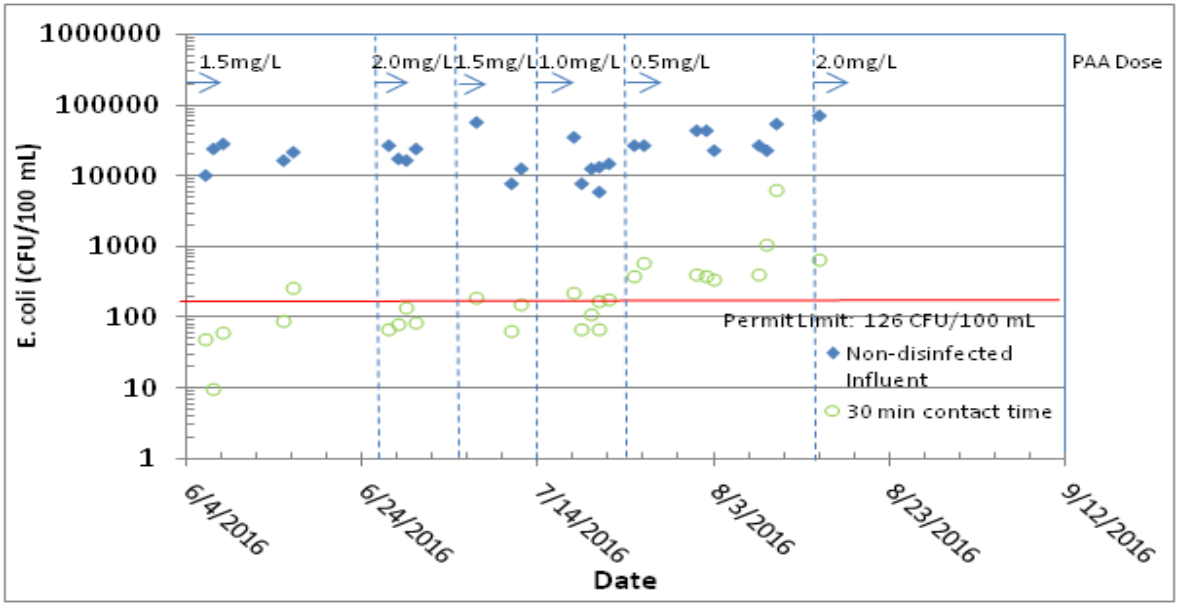

Figure 4-12 *E. coli* Concentrations at a contact time of 30 minutes.

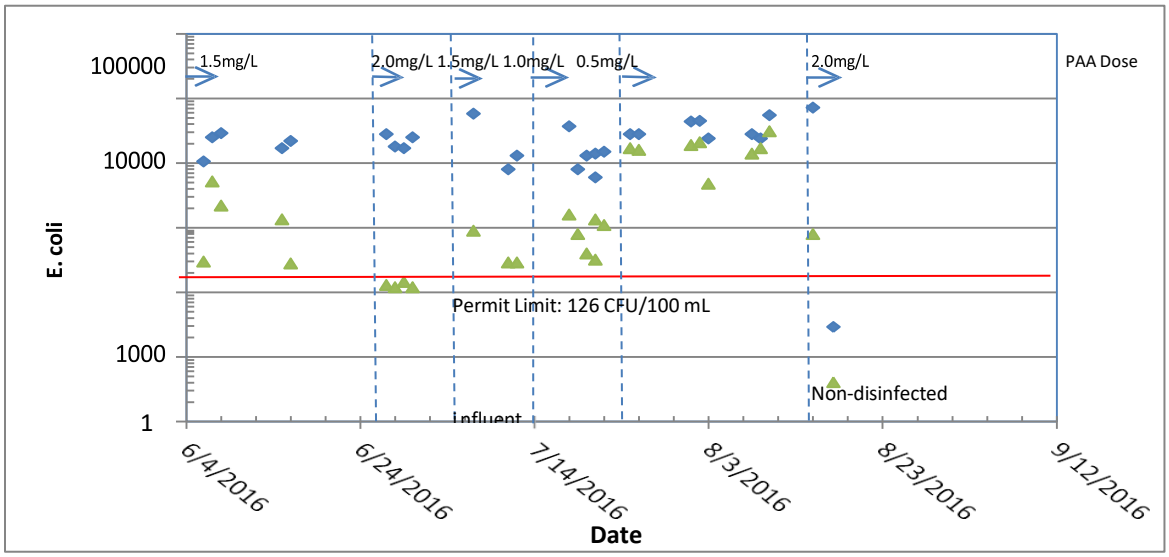

Figure 4-13 *E. coli* Concentrations at a contact time of 17 minutes.

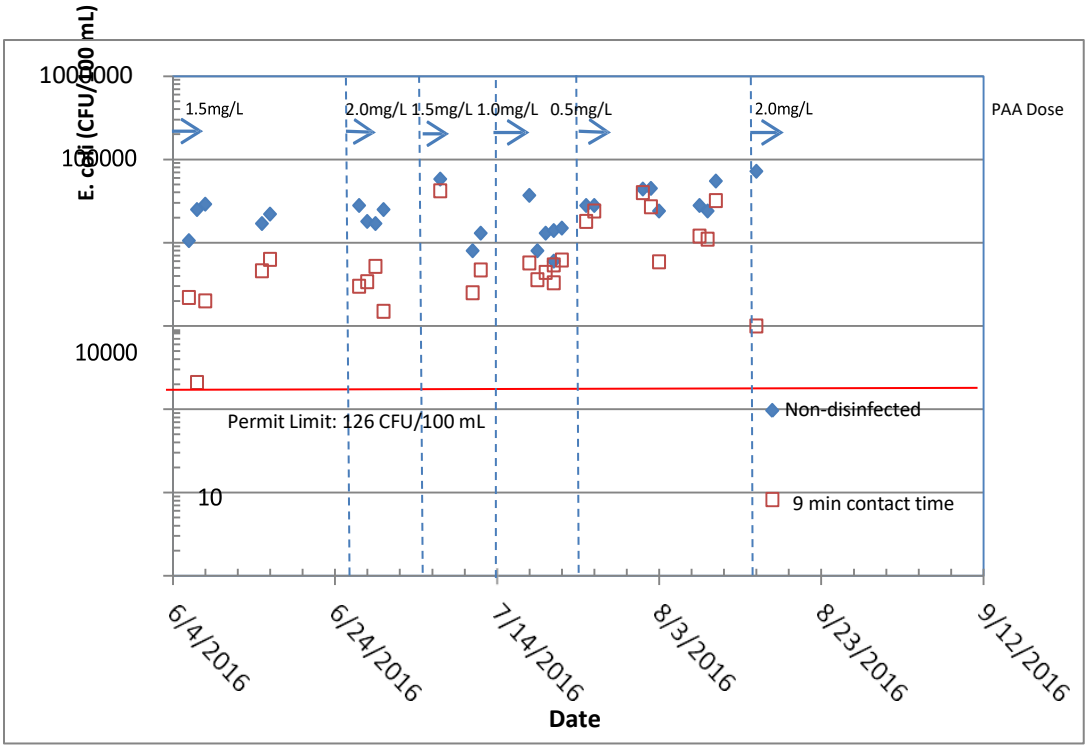

Figure 4-14 *E. coli* Concentrations at a contact time of 9 minutes.

Table 4-2 Statistical Summary of *E. coli* Concentrations

Contact Time in Minutes	*E. coli at various PAA doses at different sampling locations In CFU/100 mL (geomean)*				Potential Permit Limit in CFU/100 mL (geomean
	0.5 mg PAA/L	1.0 mg PAA/L	1.5 mg PAA/L	2.0 mg PAA/L	
30	656	**125**	91	81	**126**
17	16,764	789	636	103	
9	19,971	4,640	3736	3,677	

Geomean vales were calculated based on the available data, rather than 30-day or 7- day results.

4.6 PAA and Hydrogen Peroxide Residuals

PAA residuals in the final effluent of the DPR at the effective doses of 1.0 mg/L and 0.5 mg/L during the trial period are shown in Figure 3-11.

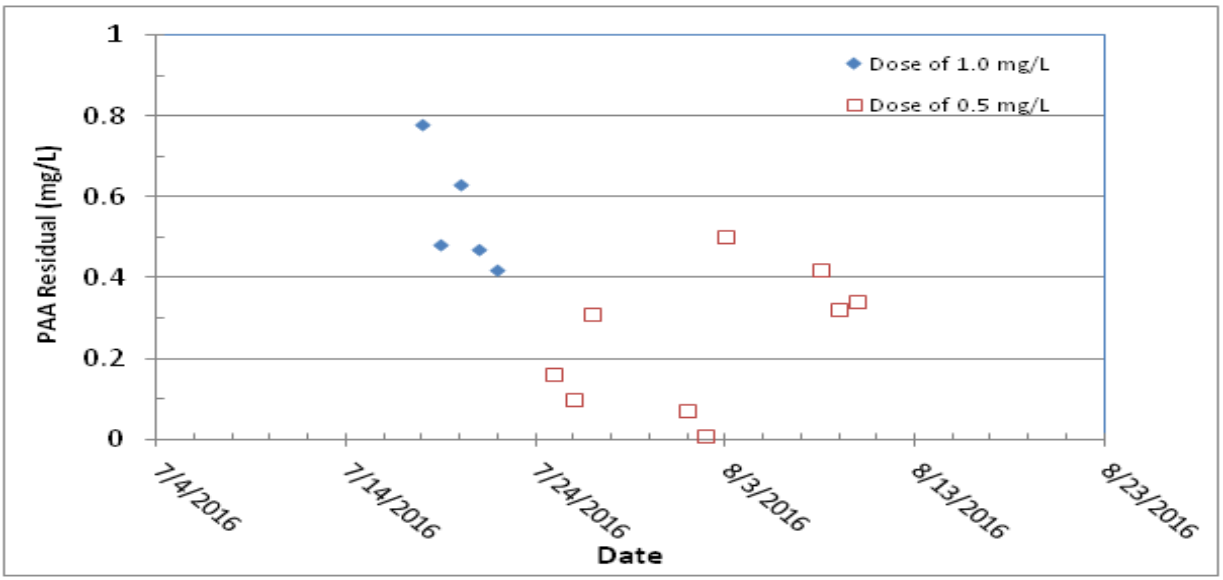

Figure 4-15 PAA Residuals in the Final Effluent of DPR at Effective Doses of 1.0 mg/L and 0.5mg/L

The site-specific discharge limit for PAA/total oxidants needs to be approved by the Ohio Environmental Protection Agency (OPEA) before any use of this method for full scale field trials. At present, we are involved in developing cost effective methods for the removal of treatment residuals from the final effluent discharge.

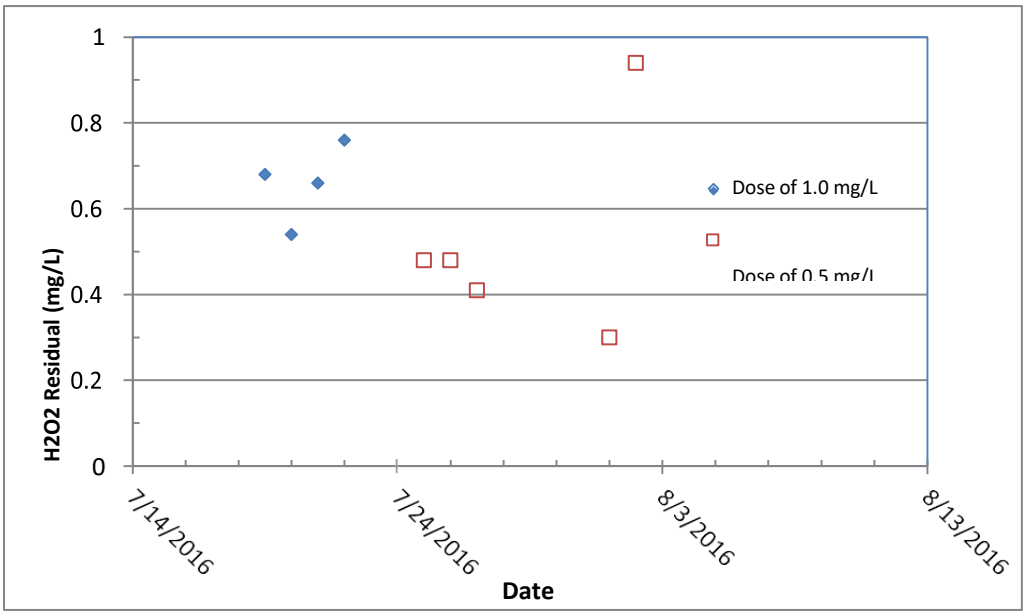

Figure 4-16 Hydrogen Peroxide Residuals in the Final Effluent of DPR at Effective Doses of 1.0 mg/L and 0.5 mg/L.

Hydrogen peroxide residuals in the final effluent of the DPR at the effective doses of 1.0 mg/L and 0.5 mg/L during the trial period are shown in Figure 4-16. The hydrogen peroxide residuals were always less than 1.0 mg/L. Since the toxicity impact of hydrogen peroxide on aquatic organisms was much lower than that of PAA, it is unlikely that it is necessary to quench hydrogen peroxide before final discharge.

4.7 Whole Effluent Toxicity (WET)

Representative DPR effluent samples were collected for WET testing in accordance to the protocol specified in the Little Miami WWTP's permit. Two sets of samples were collected under the conditions shown in Table 4-3 for the WET testing. Note the samples were taken under the PAA dosing conditions needed to achieve disinfection goals at the average and peak flow situations, thereby representative of the average and the most challenging conditions for potential toxicity impacts on aquatic organisms.

The samples were shipped to Great Lake Environmental Center (Columbus, OH) for static acute toxicity testing using two aquatic organisms, *Ceriodaphnia dubia,* and *Pimephales promelas*. The results demonstrated that, for both PAA-treated samples, the TUa (acute toxicity unit) were below detection. This demonstrated that PAA technology could be implemented as an

environmentally friendly disinfection process at this facility, without causing any compliance issue on WET or toxicity impact on the aquatic organisms of the receiving stream.

Table 4-3 Sampling Conditions for WET.

Set of Sample	Sampling Date	PAA Dose at Sampling Date mg/L	WET Testing Date	
			Started	Completed
#1	July 19, 2016	1.0	July 20 for both organisms	July 22 for *Ceriodaphnia dubia,* July 24 for *Pimephales promelas*
#2	August 15, 2016	2.0	August 16 for both organisms	August 18 for *Ceriodaphnia dubia,* August 20 for *Pimephales promelas*

5. Conclusions

Peracetic acid (PAA) was shown to provide effective bacterial reduction during field pilot trials at the Little Miami Wastewater Treatment Plant, located in Cincinnati, OH.

Key findings:

- A PAA dose rate of **1.0 mg/L** and a contact time of 30 minutes were sufficient to achieve the disinfection goal to reduce the geometric mean of fecal coliform to below 200 CFU/100 mL, which is the current permit limit value for April to October. The same dose rate and contact time were able to reduce the geometric mean of *E. coli* to below 126 CFU/100 mL.
- A PAA dose rate of **0.5 mg/L** and a contact time of 30 minutes were sufficient to achieve the disinfection goal to reduce the geometric mean of fecal coliform to below 1,000 CFU/100 mL, which is the current permit limit value for November to March.
- Whole Effluent Toxicity (WET) testing for composited samples, collected at PAA dose concentration of 1.0 and 2.0 mg / L, resulted in “passing” performance, with values for the TUa (acute toxicity unit) below detection for all the samples tested.

Proposed Next Steps:

Given the success of PAA in achieving the target microbial reductions, it is recommended that a full-scale field trial be conducted within the plants’ disinfection contact chambers to assess long-term performance under water quality and hydraulic flow conditions experienced

at the site.

References:

1. Antonelli M., Turolla, A., Mezzanotte, V., Nuizzo, C., 2013, Peracetic acid for secondary effluent disinfection: a comprehensive performance evaluation. Water Sci. Technol., 68, 2638-2644.
2. Andreottola, G., Bertola, P., Ziglio, G. (1996) Indagine sperimentale comparata sulla disinfezione di acque reflue urbane con ozono e acido peracetico. Ingegneria Ambientale 25, 200–206.
3. Baldry MGC, Cavadore A, French MS, Massa G, Rodrigues LM, Schirch PFT, et al., 1995, Effluent disinfection in warm climates with peracetic acid. Water Sci Technol, 31, 161–164.
4. Booth, R.A. & Lester, J.N. (1995) The potential formation of halogenated byproducts during peracetic acid treatment of final sewage effluent. Water Res. 29, 1793–1801.
5. Carmineo, D., Contini, E., Di Marino, R., Donadio, F., Liberti, L., Ranieri, E. (1994) Wastewater disinfection by UV at Trani municipal plant. Water Sci. Technol 30, 125–132.
6. Crebelli, R. Conti, L., Monarca, S., Feretti, D., Zerbini, I., Zani, C., Veschetti, E., Cutilli, D., Ottaviani, M., 2005, Genotoxicity of the disinfection byproducts resulting from Peracetic acid or hypochlorite disinfected sewage wastewater. Water Res., 39, 1105-1113.
7. Dell'Erba, A., Falsanisi, D., Liberti, L., Notrnicola, M., Santoro, D., 2007, Disinfection by-products formation during wastewater disinfection with peracetic acid. Desalination 215, 177–186.
8. Hajenian, H. & Butler, M. (1980) Inactivation of f2 coliphage in municipal effluent by the use of various disinfectants. Journal of Hygiene (Lond.) 84, 247–255.
9. Kauppinen, A., Ikonen, J., Pursiainen, A., Pitkänen, T., Miettinen, T., 2012, Decontamination of a drinking water pipeline system contaminated with adenovirus and Escherichia coli utilizing peracetic acid and chlorine. J. Water Health, 10, 406-418.
10. Kitis, M., 2004, Disinfection of wastewater with Peracetic acid: a review. Environ. Int., 30, 44-55.
11. Kolch, A., 2000, Sewage disinfection towards protection of drinking water. Schriftenr ver Wasseries Boden Lufthyg, 105, 331-336.
12. Koivunen, J., and Heinonen-Tanski, H., 2005, Inactivation of enteric microorganisms with chemical disinfectants, UV irradiation and combined chemical/UV treatments. Water Res. 39, 1519–1526.
13. Lazarova, V., Janex, ML, Fiksdal, L., Oberg, C., Bercina, I., Pommepuy, M., 1998, Advanced wastewater disinfection technologies: Short and long term efficiency. Water Sci Technol., 38, 109-117.
14. Legnani, P.P., Leoni, E., Baraldi, M., Pinelli, G., Bisbini, P. (1996) Evaluation of disinfection treatment systems for municipal wastewater reclamation and re-use. Zentralblatt für Hygiene und Umweltmedizin 198, 552–566.
15. Lefevre, F., Audic, JM, Ferrand, F., 1992, Peracetic acid disinfection of sewage effluents discharged off secondary coastal seawater. Water Sci Technol., 25, 155-164.

16. Liberti and Notarnicola, 1999, Advanced treatment and disinfection for municipal wastewater reuse in agriculture. Water Sci Technol, 40:235–245.
17. Monarca, S., Feretti, D., Collivignarelli, L., Zerbini, I., Bertanza, G., et al., 2000, The influence of different disinfectants on mutagenicity and toxicity of urban wastewater. Water Res., 34, 4261-4269.
18. Sanchez-Ruiz, C., Martinez-Royano, S., Tejero-Mozon, I., 1996, An evaluation of the efficiency and impact of raw wastewater disinfection with peracetic acid prior to ocean discharge, Water Sci. Technol., 32 (1995) 159–166.
19. Stampi, S., Luca, G., Zanetti, F., 2001, Evaluation of the efficiency of Peracetic acid in the disinfection of sewage effluents. J Appl. Microbiol., 91, 833-838.
20. Stampi, S., De Luca G., Onorato, M., Ambrogiani, E., Zanetti, F., 2002, Peracetic acid as an alternative wastewater disinfectant to chlorine dioxide. J. Appl. Microbiol., 93, 721-731.
21. Vaschetti, E., Cutillli, D., Bonadonna, L., Briancesco, R., Martini, C., Cecchini, G., Anastasi, P., Ottaviani, M., 2003, Pilot-plant comparative study off Peracetic acid and sodium hypochlorite wastewater disinfection. Water Res., 37, 78-94.
22. Wagner, M. Brumelis, D. Gehr, R. 2002. Disinfection of Wastewater by Hydrogen Peroxide of Peracetic Acid: Development of Procedures for Measurement of Residual Disinfectant and Application to a Physicochemically Treated Municipal Effluent. Water Environ. Res., 74 1 33- 50.
23. Zanetti, F., De Stampi, S., Luca, G., Varoli, O., Tonelli, E. (1996) Comparative disinfection of secondary-treatment sewage with chlorine dioxide and bromine chloride. Zentralblatt für Hygiene Umvelmedizine 198, 567–579.

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