PW-TRC-PDR

NYC Environmental Protection

Port Richmond Wastewater Resource Recovery Facility Process Impacts on TRC

January 2021

CDM Smith

in association with

HDR

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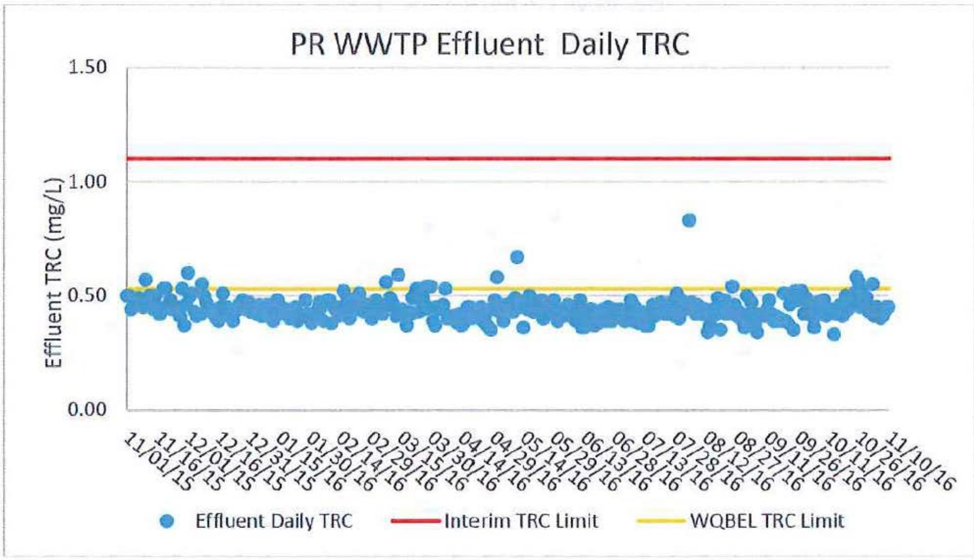
Section 1
Introduction

1.1 Background

New York City Department of Environmental Protection (NYCDEP) has completed field, laboratory and modeling studies to assess compliance with the total residual chlorine (TRC) receiving water quality criteria of 13 ug/L at the Port Richmond Wastewater Resource Recovery Facility (WRRF) by implementation of a new outfall and diffuser configuration. Based on the increased dilution that would be provided by a reconfigured outfall/diffuser system and the results of the Port Richmond chlorine decay/degradation study, a new water quality based effluent limit (WQBEL) of 0.52 mg/L would be established, pending New York State Department of Environmental Conservation (NYSDEC) approval (Port Richmond Wastewater Resource Recovery Facility Total Residual Chlorine Preliminary Design Report Addendum No. 3, 2019). It is anticipated that NYSDEC could reduce the State Pollutant Discharge Elimination System (SPDES) limit to less than 0.52 mg/L to provide a factor of safety.

The Port Richmond wastewater resource recovery facility (WRRF) had successfully complied with a TRC target of 0.53 mg/L during most of the November 2015 through November 2016 demonstration period as shown on **Figure 1-1** and during the more recent period from July 2017 through January 2019 that is shown by **Figure 1-2** (1). The data showed that the Port Richmond plant can successfully maintain a TRC effluent limit of 0.52 mg/L for sustained periods of time. The data also shows that there are periods of high effluent TRC concentrations that would result in exceedance of a new 0.52 mg/L limit. The most significant excursions above the limit (i.e., magnitude and duration of concentrations above 0.52 mg/L) occurred in December 2017 and December 2018 following significant wet weather events and resulting operational upsets.



Source: NYCDEP, please note that proposed WQBEL has been updated since this graphic was developed.

Figure 1-1 Port Richmond WWRF Compliance with Proposed WQBEL of 0.53 mg/L during Demonstration Period

(1) In 2015, NYSDEC's proposed TRC permit limit was 0.53 mg/L. In 2017, NYSDEC reduced the proposed limit to 0.20 mg/L. In 2018, DEP proposed a new limit of 0.52 mg/L based on the increased dilution provided by a new outfall diffuser.

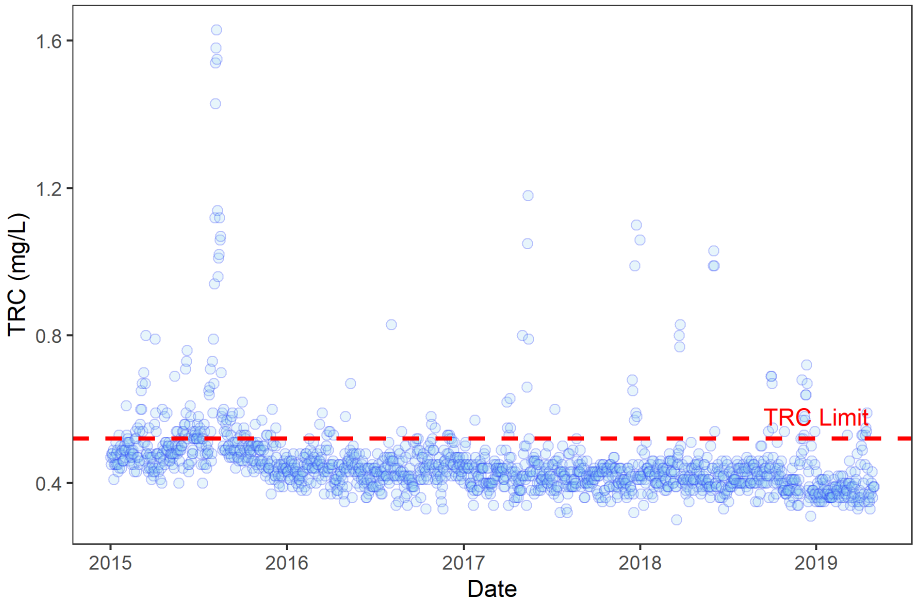


Figure 1-2 Effluent TRC Concentrations from July 2017 through January 2019

The most recent data available, summarized on **Table 1-1,** shows that Port Richmond continues to successfully achieve effluent TRC concentrations that are lower than 0.52 mg/L target most, but not all of the time.

Table 1-1 Overview of Effluent TRC Concentrations through February 2020

Port Richmond

- TRC Limit: 0.20 mg/L; Interim Limit 1.0mg/L effective date 7/1/19. (Letter dated 7/1/19)

TRC Performance

Month	Monthly Avg (mg/L)	Daily Max (mg/L)	Daily Max Limit (mg/L)	Exceedances Per Month
Apr-18	0.42	0.51	2.0	0
May-18	0.42	0.50	2.0	0
Jun-18	0.47	1.03	2.0	0
Jul-18	0.41	0.46	2.0	0
Aug-18	0.42	0.47	2.0	0
Sep-18	0.45	0.69	0.78	0
Oct-18	0.43	0.67	0.78	0
Nov-18	0.40	0.52	0.78	0
Dec-18	0.47	0.72	0.78	0
Jan-19	0.38	0.43	0.78	0
Feb-19	0.38	0.42	0.78	0
Mar-19	0.39	0.53	0.78	0
Apr-19	0.42	0.59	0.78	0
May-19	0.39	0.56	0.78	0
Jun-19	0.38	0.44	0.78	0
Jul-19	0.42	0.65	1.00	0
Aug-19	0.38	0.48	1.00	0
Sep-19	0.35	0.44	1.00	0
Oct-19	0.32	0.39	1.00	0
Nov-19	0.31	0.35	1.00	0
Dec-19	0.29	0.37	1.00	0
Jan-20	0.30	0.59	1.00	0
Feb-20	0.23	0.36	1.00	0
		Total Exceedances		0

Source: NYCDEP

Review of Port Richmond operating data indicates that there are a number of factors that contribute to inconsistent wastewater quality at the chlorine contact tanks (CCTs), prompting the disinfection challenges experienced by the plant. DEP believes the TRC excursions above the anticipated new WQBEL could potentially be resolved by understanding and improving performance of upstream plant processes.

1.2 Objectives

The objectives of this technical memorandum are to:

- Identify the factors causing inconsistent secondary effluent quality and
- Identify the infrastructure and/or operational improvements required to increase effluent consistency and support consistent achievement of an effluent TRC of less than 0.52 mg/L while maintaining compliance with permitted limits for fecal coliform.

1.3 Organization

Section 2 of this technical memorandum identifies the sources of the data that was reviewed and presents the initial data evaluations and correlations that were used to assess potential relationships between effluent total residual chlorine (TRC) and factors such as precipitation, upstream processes and other factors.

Section 3 explains the impacts of a variety of factors on disinfection effectiveness along with examples based upon effluent data.

A summary of conclusions and recommendations to improve upstream processes and disinfection system performance is provided in Section 4. Finally, the data used during this evaluation is included in Appendix A.

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Section 2

Data and Information Reviewed

Based on an initial review of available data, discussions with the Bureau of Wastewater Treatment and a site visit conducted with the Process Engineer on May 22, 2019, the following factors were identified as potential contributors to the variation in effluent total residual chlorine observed at Port Richmond:

- Precipitation/Wet Weather events;
- Process control challenges;
- Discharge from Visy Paper;
- Variation in chlorine demand and disinfection effectiveness (based on influent wastewater characteristics and/or upstream process effectiveness);
- Clarifier solids loading and flux;
- Return Activated Sludge (RAS)/Waste Activated Sludge (WAS) chlorination, and
- Sodium hypochlorite dosage control (e.g., variability in optimum dosage due to the process control system and the effects of chemical age and strength).

The plant is capable of dosing sodium hypochlorite based on residual feedback, but dosages were based on flow-pacing during the 2019 site visit. Based on the influent chlorine concentration measured by a TRC analyzer located at the CCT influent distribution channel and the plant flow signal, the sodium hypochlorite dose would be calculated. A TRC analyzer located at the effluent end of the CCTs would monitor the TRC concentration to adjust the dose (residual trim). The flow pacing approach used may be based on either influent or effluent flow. Due to concerns with the accuracy of the effluent Parshall flume, the plant typically operates using influent flow data and manually adjusts the hypochlorite dose for flow paced control. If the signal from the plant influent pumps fails, the plant switches automatically to effluent flows. The chemical feed pump is adjusted to maintain a dose setpoint.

The data and information that were collected and evaluated to identify and assess the factor(s) causing the observed inconsistency in effluent total residual chlorine levels at the Port Richmond Wastewater Resource Recovery Facility (WRRF) are summarized below.

2.1 Daily Monitoring Report Data

Historical water quality data was provided by the Port Richmond WRRF Discharge Monitoring Reports (DMR). The facility collects and logs process metrics to monitor plant performance and compliance with regulatory permits. The DMRs were provided electronically via Microsoft Excel and each contains several worksheets recording over 100 different parameters. Variables that may have a potential relationship to disinfection were extracted and used for assessing potential impacts to disinfection performance. **Table 2-1** provides a quick summary of 65 variables that were extracted for statistical evaluation.

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Table 2-1 Parameters Potentially Impacting Disinfection at Port Richmond WWRF	Sample Count			Mean			Standard Deviation		
	All Data[1]	Period of Performance[2]	After Upgrade[3]	All Data[1]	Period of Performance[2]	After Upgrade[3]	All Data[1]	Period of Performance[2]	After Upgrade[3]
CBOD - Plant Effluent.mg/L	1,585	367	1,160	9.1	8.9	9.5	8.8	7.4	9.1
CBOD - Primary Effluent.mg/L	678	157	493	265.2	311.8	261.2	170.2	162.0	134.8
CBOD - Raw Sewage.mg/L	1,585	367	1,160	320.0	353.8	330.7	109.0	116.1	113.6
CBOD - Plant Effluent lbs/day	1,547	360	1,130	2,175.4	2,028.8	2,235.7	2,573.1	2,238.6	2,588.9
CBOD - Plant Influent mg/L	1,585	367	1,160	320.0	353.8	330.7	109.0	116.1	113.6
CBOD Influent lbs/day	1,546	360	1,131	69,184.9	72,744.3	70,567.5	22,649.2	24,750.3	23,962.2
Chlorides Plant Influent mg/L	226	53	166	472.7	466.9	467.3	321.3	283.2	302.9
Chlorine Dose .mg/L	1,579	367	1,154	2.1	2.3	2.0	1.0	0.9	0.9
Chlorine Residual @Time of Fecal Sample mg/L	1,585	367	1,160	0.4	0.4	0.4	0.2	0.1	0.1
Chlorine Residual Avg. mg/L	1,585	367	1,160	0.5	0.4	0.4	0.1	0.0	0.1
Chlorine Tank 1 Delivery. Gallons	1,581	367	1,156	580.2	577.1	570.2	1,599.0	1,582.4	1,588.0
Chlorine Tank 2 Delivery. Gallons	1,579	365	1,154	8.4	11.6	11.4	193.0	221.6	225.7
Chlorine Tank 3 Delivery. Gallons	1,125	215	1,125	0.0	0.0	0.0	0.0	0.0	0.0
Chlorine Tank Delivery Totals. Gallons	1,581	367	1,156	588.6	588.6	581.6	1,614.6	1,623.9	1,609.5
Chlorine Target Concentration.mg/L	1,459	367	1,155	0.4	0.4	0.4	0.0	0.0	0.0
Chlorine Usage for Disinfection. Gallons	1,584	367	1,159	378.3	396.9	347.8	185.2	186.1	161.1
Aeration Tank Cylinders Average mL/L	1,584	366	1,159	191.4	175.9	203.0	107.7	94.0	115.7
Detention Period - Aeration Tanks. Hours	1,585	367	1,160	8.3	8.6	8.4	1.3	1.1	1.3
Detention Period - Final Tanks. Hours	1,585	367	1,160	5.9	5.8	5.9	1.2	1.0	1.3
Detention Period - Primary Tanks. Hours	1,585	367	1,160	2.5	2.6	2.5	0.6	0.6	0.6
Dissolved Oxygen (Aeration).mg/L	1,564	365	1,152	4.7	4.6	4.5	1.3	1.0	1.3
CCT Effluent Enterococcus. Cfu/100mL	41	11	38	41.2	1.9	44.3	164.8	2.1	170.9
CCT Effluent Fecal Coliform - 7 day geomean. Cfu/100mL	182	42	132	57.1	28.3	67.6	64.1	28.9	65.2
CCT Effluent Fecal Coliform. Cfu/100mL	1,584	367	1,159	156.3	88.6	163.3	404.8	306.2	379.7

Table 2-1 Parameters Potentially Impacting Disinfection at Port Richmond WWRF	Sample Count			Mean			Standard Deviation		
	All Data[1]	Period of Performance[2]	After Upgrade[3]	All Data[1]	Period of Performance[2]	After Upgrade[3]	All Data[1]	Period of Performance[2]	After Upgrade[3]
Flow - Plant Influent MGD	1,585	367	1,160	27.3	25.4	26.9	9.4	6.9	9.5
Flow (dry) - Plant Influent MGD	1,585	367	1,160	24.0	23.7	23.3	3.4	3.6	3.0
Mean Cell Residence Time. Days	906	233	633	4.7	4.0	4.8	8.5	1.6	10.1
NH_3 Plant Effluent.mg/L	231	53	165	5.4	5.9	5.8	2.7	1.6	2.8
NH_3 Plant Influent.mg/L	226	53	165	18.2	22.2	18.2	6.1	5.8	6.1
NO_2 Plant Effluent.mg/L	227	53	165	0.5	0.6	0.5	0.3	0.3	0.3
NO_2 Plant Influent.mg/L	226	53	165	0.3	0.2	0.3	0.2	0.2	0.2
NO_3 Plant Effluent.mg/L	231	53	165	1.3	1.5	0.9	1.1	1.2	0.8
NO_3 Plant Influent.mg/L	226	53	165	0.2	0.2	0.2	0.3	0.3	0.2
Orthophosphate Plant Effluent.mg/L	104	24	76	0.9	1.2	0.8	0.6	0.4	0.5
Orthophosphate Plant Influent.mg/L	104	24	76	1.9	2.0	2.0	0.5	0.5	0.6
pH Plant Effluent	1,585	367	1,160	6.9	6.9	6.9	0.1	0.1	0.1
pH Plant Influent	1,585	367	1,160	6.8	6.8	6.8	0.1	0.1	0.1
Return Sludge Percent of Sewage Flow.%	1,585	367	1,160	0.6	0.6	0.6	0.1	0.1	0.1
Settleable Sludge Volume (30 min).mg/L	1,584	366	1,159	191.4	175.9	203.0	107.7	94.0	115.7
Sludge Age (days)	912	236	642	8.9	8.3	8.7	4.8	4.3	4.6
Sludge Density Index	851	202	613	0.8	0.9	0.8	0.5	0.5	0.4
SS Activated Sludge Aerator.mg/L	898	208	657	1,359.5	1,409.9	1,300.0	474.6	465.9	465.8
SS Aerator Effluent.mg/L	895	206	656	930.9	920.1	897.7	319.6	266.0	325.0
SVI	896	207	655	159.2	140.0	174.7	94.0	82.7	99.0
Temperature Plant Effluent.C	1,585	367	1,160	18.4	19.8	18.4	4.6	4.0	4.4
Temperature Plant Influent.C	1,585	367	1,160	18.4	19.8	18.4	4.6	4.0	4.4
TKN Plant Effluent.mg/L	225	53	165	8.4	8.3	8.6	2.9	2.2	2.9
TKN Plant Influent.mg/L	226	53	165	31.9	33.7	31.9	6.5	4.7	6.7
Total Phosphorus Plant Effluent.mg/L	104	24	76	1.6	2.0	1.5	1.1	1.1	0.9
Total Phosphorus Plant Influent.mg/L	104	24	76	3.9	4.4	3.8	1.1	0.9	1.0

Table 2-1 Parameters Potentially Impacting Disinfection at Port Richmond WWRF	Sample Count			Mean			Standard Deviation		
	All Data[1]	Period of Performance[2]	After Upgrade[3]	All Data[1]	Period of Performance[2]	After Upgrade[3]	All Data[1]	Period of Performance[2]	After Upgrade[3]
TSS Aerator Effluent.mg/L	1,555	360	1,138	1,569.5	1,572.8	1,490.6	607.6	441.9	655.8
TSS Avg Aerator.mg/L	867	203	629	1,358.8	1,409.5	1,298.7	475.5	466.2	468.8
TSS Plant Effluent Concentration. (mg/L)	1,555	360	1,138	8.7	9.2	8.2	11.9	12.4	11.2
TSS Plant Effluent Loading lbs/day	1,515	360	1,098	2,236.8	2,229.1	2,080.6	3,911.3	4,128.6	3,605.3
TSS Plant Influent Loading lbs/day	1,552	360	1,137	39,153.5	46,717.9	36,960.6	21,463.0	30,396.2	21,306.8
TSS Percent Removal %	1,513	360	1,098	94.3	95.4	94.3	8.3	5.9	8.6
TSS Plant Effluent mg/L	1,585	367	1,160	8.7	9.2	8.2	11.9	12.3	11.1
TSS Plant Influent mg/L	1,585	367	1,160	177.8	221.1	170.4	94.8	128.4	92.7
Waste Activated Sludge lbs/day	1,585	367	1,160	35,869.4	31,550.4	36,242.1	10,787.3	7,807.4	10,935.3

[1] – Entire dataset from DEP Daily Monitoring Reports were collected and summarized for the periods 1/1/2015 - 4/30/2019.
[2] – Period of Performance that overlaps with dataset includes 11/1/2015 – 11/1/2016.
[3] – After Upgrade refers to a subset of the data where the chlorination system was upgraded and operational from 3/1/2016 onwards.

Data in **Table 2-1** are summarized by mean and standard deviation to provide insight into sample spreads. Plant performance may have changed during the 4-year period of data provided. Notable periods include the *Period of Performance* – a 12-month period during which the facility targeted the proposed TRC limit (0.53 mg/L) while maintaining required bacterial effluent concentrations, and the *Post-Chlorination Upgrade* – a period after new chlorination system upgrades were constructed and fully operational. Due to these operational periods, three facets of statistics are provided for this dataset summarizing information from:

- Entire dataset (1/1/2015 - 4/30/2019)
- Period of Performance (11/1/2015 - 11/1/2016)
- Post-Chlorination Upgrade (All data after 3/1/2016; partial overlap with Period of Performance)

2.2 PLC Data

After reviewing data from the DMRs, additional granular information on the disinfection process when high values of TRC were measured was provided. Data from Port Richmond WRRF programmable logic controllers (PLC) was provided by DEP for the times of high reported TRC shown on **Figure 2-1** and listed in **Table 2-2.** This data is collected at the facility in 1-minute time increments. Because of this discretization, the data was only requested for specific disinfection events of interest for fine-tuned assessment.

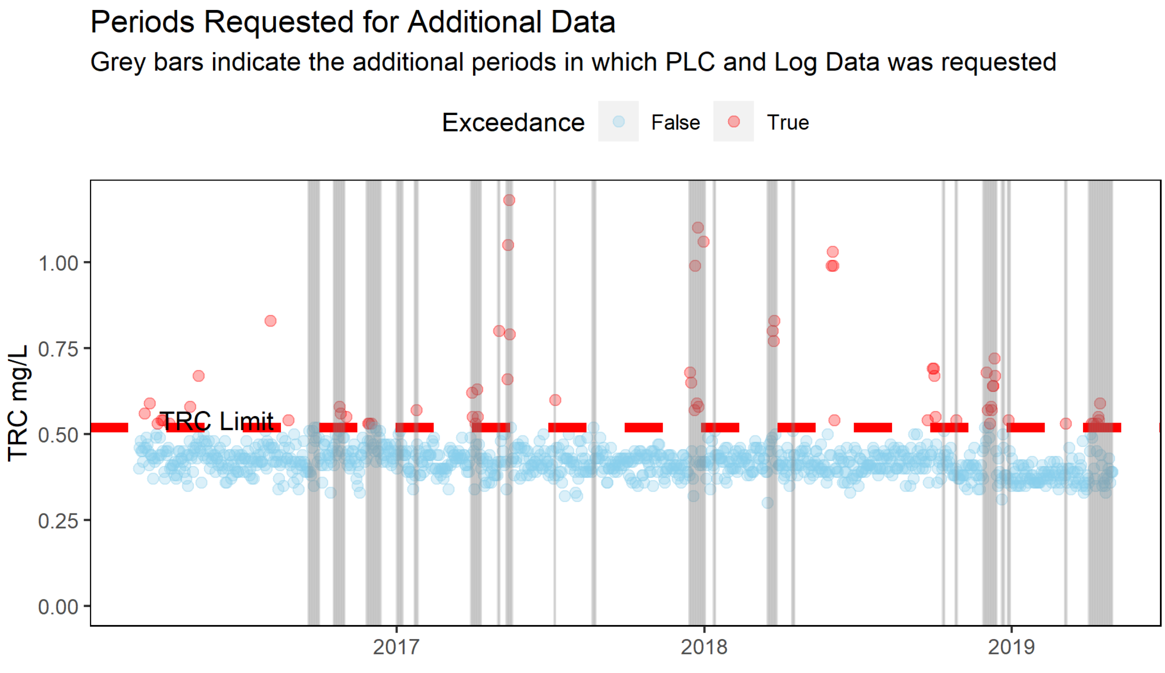

Figure 2-1 Timeframes for Detailed Data Evaluation

Examples of evaluations from these specific periods can be found in **Section 3**.

Table 2-2 Timeframes for Detailed Data Evaluation

Period	PLC & Log Data Request
1	09/18/2016 - 10/01/2016
2	10/18/2016 - 10/31/2016
3	11/26/2016 - 12/13/2016
4	01/01/2017 - 01/08/2017
5	01/22/2017 - 01/26/2017
6	03/30/2017 - 04/11/2017
7	05/01/2017 - 05/03/2017
8	05/11/2017 - 05/18/2017
9	07/07/2017 - 07/08/2017
10	08/21/2017 - 08/25/2017
11	12/14/2017 - 01/02/2018
12	01/12/2018 - 01/14/2018
13	03/17/2018 - 03/28/2018
14	04/15/2018 - 04/18/2018
15	10/11/2018 - 10/13/2018
16	10/26/2018 - 10/28/2018
17	11/28/2018 - 12/14/2018
18	12/20/2018 - 12/23/2018
19	12/27/2018 - 12/30/2018
20	03/05/2019 - 03/07/2019
21	04/02/2019 - 04/30/2019

Data in **Table 2-3** is summarized by mean and standard deviation to provide insight into sample spreads. Plant performance may have changed during the 4-year period of data provided. Notable periods include the *Period of Performance* – 12-month period during which the facility targeted the proposed new TRC limit of 0.53 mg/L while maintaining required bacterial effluent concentrations, and *Post-Chlorination Upgrade* – period after new chlorination system upgrades were constructed and fully operational. Due to these distinct operating periods, three facets of statistics are provided for this dataset summarizing information from:

- Entire dataset (Data Ranges specified in **Table 2-2**)
- Period of Performance (11/1/2015 - 11/1/2016) (See **Table 2-3** footnote)

Table 2-3 Detailed Data Provided by PLC Logs

Parameter	Sample Count		Mean		Standard Deviation	
	All Data[1]	Period of Performance[2]	All Data[1]	Period of Performance[2]	All Data[1]	Period of Performance[2]
Calculated.Hypo.Dose GPH	251,751	40,117	15.8	14.5	11.5	6.9
CDM_Calculated_Dose GPH[[3]	251,753	40,118	15.7	14.4	11.3	6.7
CDM_Calculated_Dose mg/L[3]	60,531	10,770	2.9	2.2	4.8	1.3
CDM Calculated Chlorine Demand.mg/L(Prominent)	251,753	40,118	0.3	0.4	0.6	0.5
Diffuser Dose (mg/L)	251,751	40,117	1.8	2.6	0.6	0.7
Effluent Flow MGD	251,751	40,117	28.7	20.0	16.8	8.6
Emergency Tank Level (gallons)	251,751	40,117	972.1	998.1	117.3	53.8
FI.001 (MSP 1 flow MGD)	251,753	40,118	5.6	1.1	10.6	5.4
FI.002 (MSP 2 flow MGD)	251,753	40,118	5.8	6.7	10.7	11.4
FI.003 (MSP 3 flow MGD)	251,753	40,118	5.9	10.6	10.8	13.2
FI.004 (MSP 4 flow MGD)	251,753	40,118	9.9	4.9	12.6	9.9
FI.005 (MSP 5 flow MGD)	251,753	40,118	5.1	4.7	10.0	10.0
FI.006 (MSP 6 flow MGD)	251,753	40,118	4.7	2.4	10.1	7.6
Hypo Flow gph	251,751	40,117	16.6	14.5	11.2	7.0
Influent Flow MGD	251,753	40,118	37.0	30.4	16.9	9.4
Mixer Dose (mg/L)	251,751	40,117	1.5	1.7	1.2	0.3
PI.4210.GPH	251,751	40,117	3.9	1.1	12.7	6.0
PI.4211.GPH	251,751	40,117	0.6	0.2	5.6	3.5
PI.4212.GPH	251,751	40,117	8.7	13.1	7.0	4.3
PI.4213.GPH	251,751	40,117	1.1	0.0	3.6	0.1
PI.4214.GPH	251,751	40,117	1.3	0.0	4.3	0.6
Prominent Effluent.Cl.Res (mg/L)	251,751	40,117	0.6	0.5	0.6	0.5
Prominent Influent Cl.Res (mg/L)	251,751	40,117	0.9	0.9	0.4	0.2
Tank.4201.Level (gallons)	251,751	40,117	4,481.7	2,911.7	2,025.7	1,212.0
Tank.4202.Level (gallons)	251,751	40,117	5,276.3	6,195.1	1,949.4	956.1
Tank.4203.Level (gallons)	251,751	40,117	5,121.6	6,100.9	2,138.2	190.5
Total MSP Flow MGD	251,753	40,118	37.0	30.4	16.9	9.4
Total PI Pump Flow (Hypo GPH)	251,753	40,118	15.6	14.4	11.5	7.2
Total Tank Level (gallons)	251,753	40,118	15,851.7	16,205.4	2,783.7	1,785.0

[1] – Entire dataset provided for the periods 9/18/2016 - 4/18/2019
[2] – Period of Performance that overlaps with dataset includes 9/18/2016 – 11/1/2016
[3] – CDM calculated pump flow and dose based on 15% trade sodium hypochlorite solution and MSP flow rate

2.3 Process Logs

In addition to PLC data for the periods specified in **Table 2-2**, operator log sheets were provided. 228 log sheets that contain instrumentation readings as well as comments from operators regarding calibration checks, target dose changes, and notable weather conditions were transcribed for electronic use. A sample of these sheets is provided in **Appendix A** and transcribed data is /summarized in **Table 2-4.** Similar to the PLC data, the periods summarized are for:

- Entire dataset (Data Ranges specified in **Table 2-1**)
- Period of Performance (11/1/2015 - 11/1/2016) (See **Table 2-1** footnote)
- Post-Chlorination Upgrade (All data after 3/1/2016)

Table 2-4 Disinfection Information from Process Logs

Parameter	Sample Count		Mean		Standard Deviation	
	All Data[1]	Period of Performance[2]	All Data[1]	Period of Performance[2]	All Data[1]	Period of Performance[2]
Chlorine Demand.(HACH) (mg/L)	4,851	807	0.4	0.5	0.5	0.3
Eff.Flow.mgd	4,850	806	27.7	20.4	15.1	8.9
Hach effluent.(mg/L)	4,850	806	0.5	0.5	0.3	0.2
Hach Influent.(mg/L)	4,850	807	0.9	0.9	0.5	0.3
Mixer Dose.(mg/L)	1,728		0.7		0.5	
Prominent Effluent.(mg/L)	4,665	790	0.6	0.5	0.7	0.3
Prominent Influent.(mg/L)	4,833	800	0.9	0.9	0.5	0.2
Total Pump flow GPH	4,832	807	17.1	15.0	11.7	8.3

[1] – Entire dataset for process logs were collected and summarized for the periods 8/3/2016 - 12/16/2019. Process log data were only collected for specific chlorine events, the dates of these events
[2] – Period of Performance that overlaps with dataset includes 9/18/2016 – 11/1/2016

2.4 Pratt/Visy Paper Data

The Port Richmond WRRF receives wastewater from a paper processing/recycling facility in Staten Island. Industrial waste has the potential to affect the quality and characteristics of sewage and can affect treatability, including disinfection. Data characterizing this facility's wastewater was provided for the period of 1/1/2018 – 4/30/2019 and included daily flows, weekly BOD and CBOD grab samples, and sporadic results for other analytical parameters. The list of parameters and simple statistics are summarized in **Table 2-5.**

Table 2-5 Pratt/Visy Paper Discharge Characteristics

Parameter[1]	Sample Count	Mean	Standard Deviation
Benzene (Lbs/Day)	1	25,457	-
Biochemical Oxygen Demand (Lbs/Day)	66	34,168	9,497.3
Cadmium (mg/L)	7	0	0.0
Carbonaceous Biochemical Oxygen Demand (Lbs/Day)	66	31,921	8,268.8
Chromium (Hexavalent)(mg/L)	7	1	1.9
Chromium (Total) (mg/L)	8	0	0.0
Copper (mg/L)	8	0	0.0
Cyanide (Total) (mg/L)	9	0	0.0
Daily Flow (GPD)	512	625,485	139,416.8
Lead (mg/L)	8	0	0.0

Parameter[1]	Sample Count	Mean	Standard Deviation
Mercury (mg/L)	8	0	0.0
Molybdenum (mg/L)	8	0	0.0
Nickel (mg/L)	8	0	0.0
Non-Polar Material (mg/L)	80	2	0.3
Oil and Grease (mg/L)	84	2	0.9
Silver (mg/L)	7	0	0.0
Sulfates (mg/L)	1	267	-
Total Kjeldahl Nitrogen (Lbs/Day)	14	85	36.9
Total Suspended Solids (Lbs/Day)	35	542	1,322.2
Zinc (mg/L)	8	0	0.1

[1]- Visy Paper data summary statistics from 1/1/2018 - 4/30/2019

Port Richmond noted filamentous growth at their facility on multiple occasions which may in part be associated with the discharge from Pratt/Visy Paper, which is a high-strength, low-flow discharge. The Pratt/Visy Paper waste stream is high in CBOD and low in nitrogen (CBOD:TKN ratio of 2,010:5) which can contribute to sludge bulking and filamentous growth due to high food-to-mass (F:M) ratio and limiting nutrients. Additional contributing factors can include insufficient dissolved oxygen, temperature, pH, and carbon source.

2.5 Sampling Program

2.5.1 Purpose and Scope

The purpose of sampling at the Port Richmond Wastewater Resource Recovery Facility (WRRF) is to characterize the variability of pathogen indicators in wastewater entering the facility, after primary treatment, after secondary treatment and after disinfection, to assess the impact of upstream processes upon disinfection effectiveness. Samples of chlorine contact tank (CCT) effluent, final tank effluent, primary effluent and plant influent were collected by Macan Deve Engineers (MDE) and transported to New York Environmental Consultants and Laboratories (NYE) where testing was conducted to assess disinfection. Field parameters and analysis performed included temperature, pH, and total residual chlorine.

2.5.2 Testing

Samples of CCT effluent, final tank effluent, primary effluent and plant influent were collected daily (Monday through Friday) for a 12-day sampling period starting 6/29/2020 and ending 7/17/2020. Sampling was not performed on 7/2/2020 – 7/6/2020 due to the observation of July 4th holiday. Samples were collected from the sampling locations shown in **Figure 2-2,** moving sequentially from the effluent end of the CCT upstream to the plant influent; e.g., from the most highly treated sample location to untreated wastewater, and were transported by members of the field sampling team to NYE's laboratory. See PW-TRC-PDR *Port Richmond WRRF Field Sampling Plan* for specific details on the sampling locations and sampling plan.

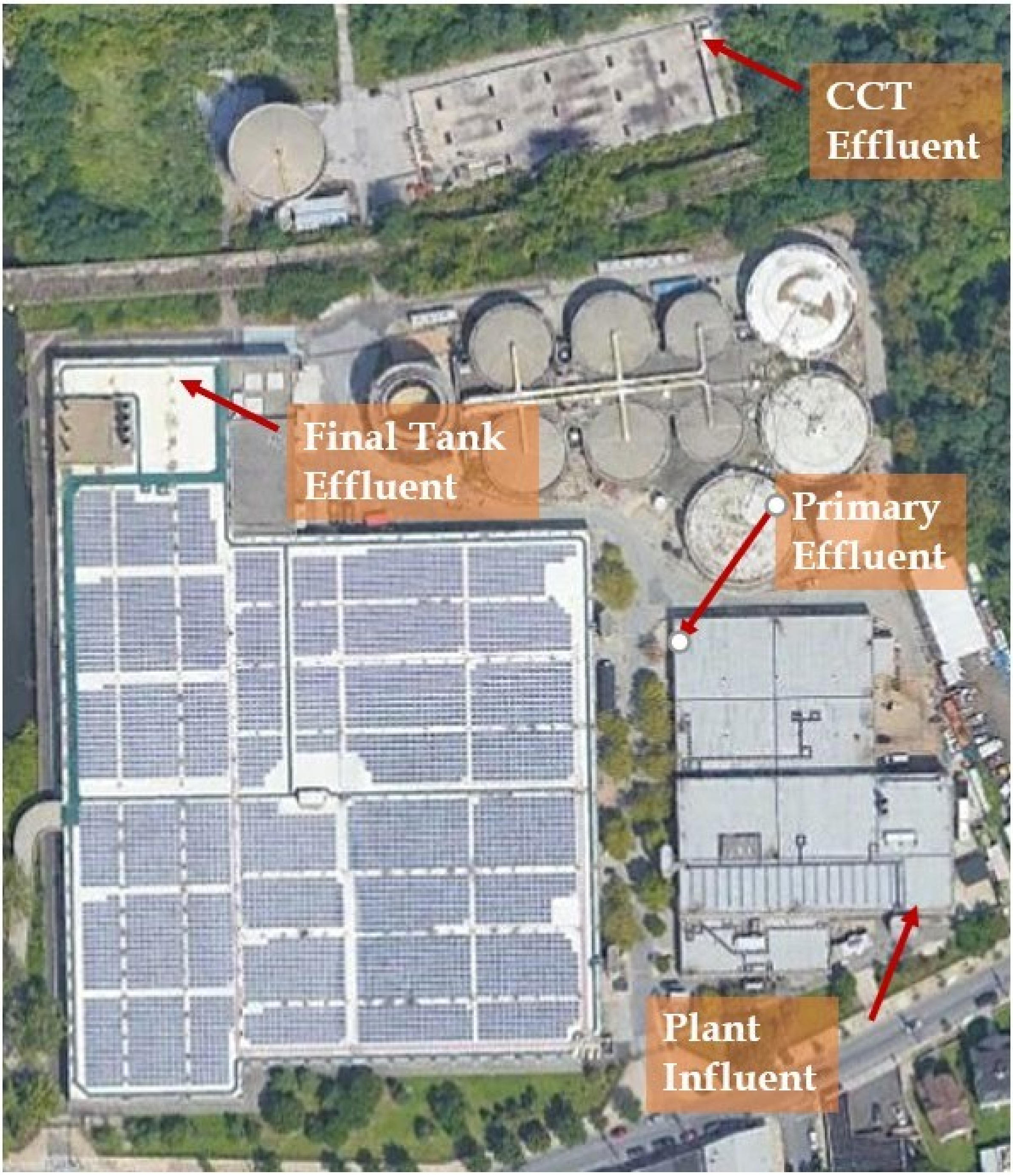

Figure 2-2 Port Richmond Sampling Locations

The 10-day sampling program was extended to 12 days to collect additional samples at each location and the full count of measurements is provided in **Table 2-6**. Results from one carbonaceous biological oxygen (cBOD) and one total suspended solids (TSS) sample were not analyzed as they exceeded their holding times during shipment. The fecal coliform samples collected on five days could not be used due to an apparent equipment malfunction at the NYE laboratory. Duplicate measurements of fecal coliform and enterococcus were collected at the final tank effluent for QA/QC and to capture supplementary data for the influent bacterial loading into the chlorine contact tanks. DEP provided additional data at the end of the sampling program for each of the days sampled including sludge volume index (SVI), sludge cylinder reading, and mixed liquor suspended solids (MLSS) concentrations.

Table 2-6 Number of Samples Collected from Each Sample Location

Parameter	Parameter Abbreviation	Plant Influent	Primary Effluent	Final Tank Effluent	CCT Effluent	Aeration Tank Effluent
Fecal Coliform	FC	12	12	24	12	-
Enterococcus	EC	12	12	24	12	-
TSS	TSS	12	12	12	12	-
cBOD	cBOD	12	12	12	12	-
Lab TRC[1]	LTRC	-	-	2	-	-
Particle Size Distribution XAD	XAD	-	-	-	-	2
pH	pH	12	12	12	12	-
Temperature	T	12	12	12	12	-
Field TRC	FTRC	12	12	12	12	-
SVI	SVI	-	-	-	-	12
MLSS	MLSS	-	-	-	-	9
Cylinder Reading Average	CRA	-	-	-	-	12
Flow	Flow	12	-	-	-	-

[1] – Lab TRC represents 5-gallon sample taken to perform chlorine demand test

2.5.3 Sampling Program Results

Sampling and analytical results for pathogen indicators, TRC, cBOD, TSS, chlorine demand testing, particle size distribution and mixed liquor suspended solids (MLSS), plant flow and SVI are all discussed. DEP provided notes for each of the sampling days which include information pertinent to plant performance and disinfection. Process control information on chlorine target residual was provided. The target residual was increased three times throughout the 12-days of sampling program. During the initial days of the sampling program, DEP maintained a residual target of 0.25 mg/L which is relatively low in comparison to the residual target of 0.4 mg/L identified in Port Richmond's historical daily monitoring reports (DMRs). The residual target was increased to 0.35 mg/L on July 7th (the 4th sampling day) and then to 1 mg/L on July 10th (the 7th sampling day). This residual target increase is likely due to the relatively high effluent bacteria concentrations observed the days prior. The residual target was reduced to 0.45 mg/L on July 13th (the 8th sampling day) where it stayed for the remainder of the program.

Another chlorine application point at Port Richmond is within the returned activated sludge (RAS). RAS is chlorinated to mitigate bulking sludge and filamentous organism growth that may be caused by poor aeration control. DEP has provided information on RAS chlorination and during the first four sampling days, the chlorine dose was relatively high at 8.8 mg/L. This may explain why the TRC target was reduced to 0.25 mg/L. RAS chlorination was reduced to 6.3 mg/L on the 4th day of sampling (and the chlorine residual target was increased to 0.35 mg/L) and then dropped to 0 mg/L from the 8th day onward. Additional details on foaming, precipitation, and other notes can be found in **Table 2-7.**

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Table 2-7 DEP Sampling Program Notes

Day	Date	TRC Target (mg/L)	RAS Chlor Dose (mg/L)	Foaming Condition	Rain Day (Yes/No)	Contractor work*	MLSS (mg/L)	Notes
1	6/29/2020	0.25	8.8	Heavy	No	--	1160	Experienced foaming as a result of M. Parvicella filaments
2	6/30/2020	0.25	8.8	Heavy	No	Yes	1070	Contractor work on June 30th and July 14th required the primary sludge pumping to be off during the sampling time period which may have affected the quality of primary effluent.
3	7/1/2020	0.25	8.8	Heavy	Yes	--	980	
(NO SAMPLING)	7/2/2020	0.25	8.8	Heavy	Yes	--	800	
4	7/7/2020	0.35	6.3	Medium	No	--	1020	
5	7/8/2020	0.35	6.3	Medium	No	--	780	
6	7/9/2020	0.35	6.3	Light	No	--	670	
7	7/10/2020	0.35 to 1.0	6.3	Light	Yes	--	560	
8	7/13/2020	0.45	Off	None	No	--	770	
9	7/14/2020	0.45	Off	None	No	Yes	765	Contractor work on June 30th and July 14th required the primary sludge pumping to be off during the sampling time period which may have affected the quality of primary effluent.
10	7/15/2020	0.45	Off	None	No	--	760	
11	7/16/2020	0.45	Off	None	No	--	770	
12	7/17/2020	0.45	Off	None	No	--	780	

2.5.3.1 Bacterial Results

Treated effluent from the Port Richmond WRRF discharges to the Kill Van Kull, which is identified as a Class SD water by the Department of Environmental Conservation (DEC). The best usage of Class SD waters is fishing. Class SD waters must be suitable for fish, shellfish and wildlife survival and the water quality shall be suitable for primary and secondary contact recreation, although other factors may limit these uses. New York State also identifies that Class SD waters may not meet the requirements for fish propagation due to natural or man-made conditions.

The existing DEC State Pollutant Discharge Elimination System (SPDES) discharge permits for all fourteen of the City's WRRFs require year-round disinfection and include limits for fecal coliform. Port Richmond WRRF SPDES permit NY0026107 includes the following effluent limits for fecal coliform:

30-day geometric mean fecal coliform:	200/100 mL
7-day geometric mean fecal coliform:	400/100 mL
6-hour geometric mean fecal coliform	800/100 mL
Instantaneous maximum fecal coliform:	2400/100 mL

In November 2012, EPA published the 2012 recreational water quality criteria (RWQC) recommendations which recommended the use of enterococcus as a pathogenic indicator organism for marine recreational waters. The 2012 RWQC includes both a geometric mean and a statistical threshold value (STV); it also defines a magnitude, duration, and frequency of excursion for both the geometric mean and the STV specifically for enterococcus.

The anticipated future permit requirement for enterococcus from the 2012 RWC is as follows:

Recommendation based on estimated illness rate of 36/1000:

30-day geometric mean fecal coliform:	35/100 mL
Statistical threshold value:	130 /100mL

Recommendation based on estimated illness rate of 32/1000:

30-day geometric mean fecal coliform:	30/100 mL
Statistical threshold value:	110/100mL

Results for fecal coliform and enterococcus at each sampling location are presented as a time series in **Figure 2-3** (two values are shown for final tank effluent each day, as duplicate samples were collected and analyzed). **Figure 2-4** provides a box plot distribution of these bacterial concentrations at each location to show the variability of bacterial concentrations observed.

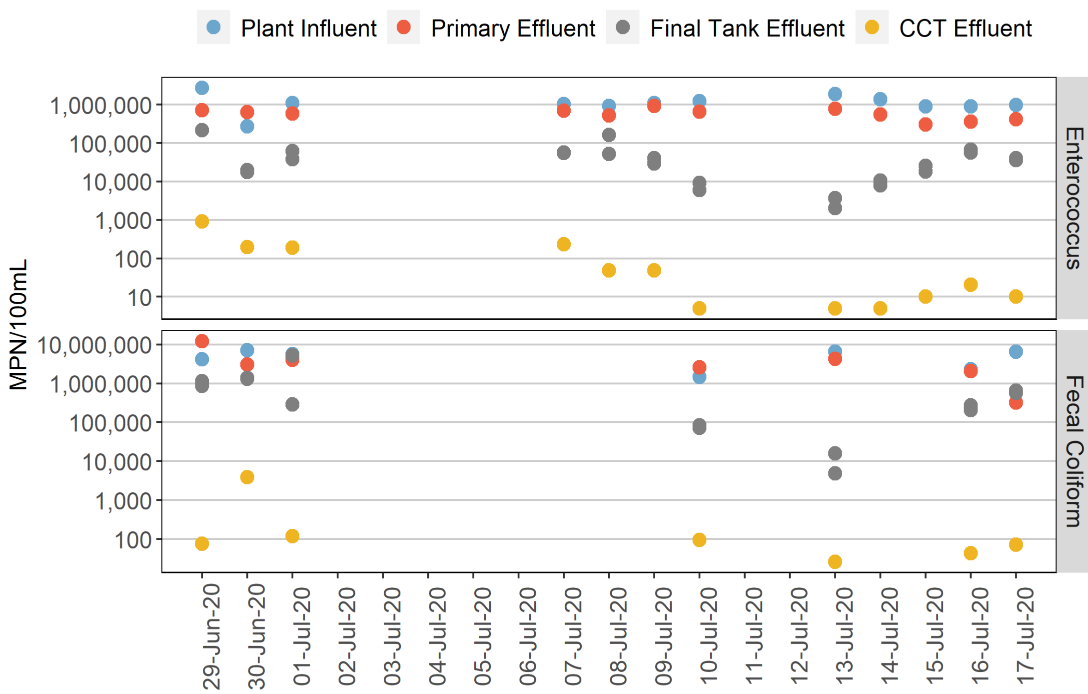


Figure 2-3 Port Richmond Bacterial Concentrations Sampling Time Series

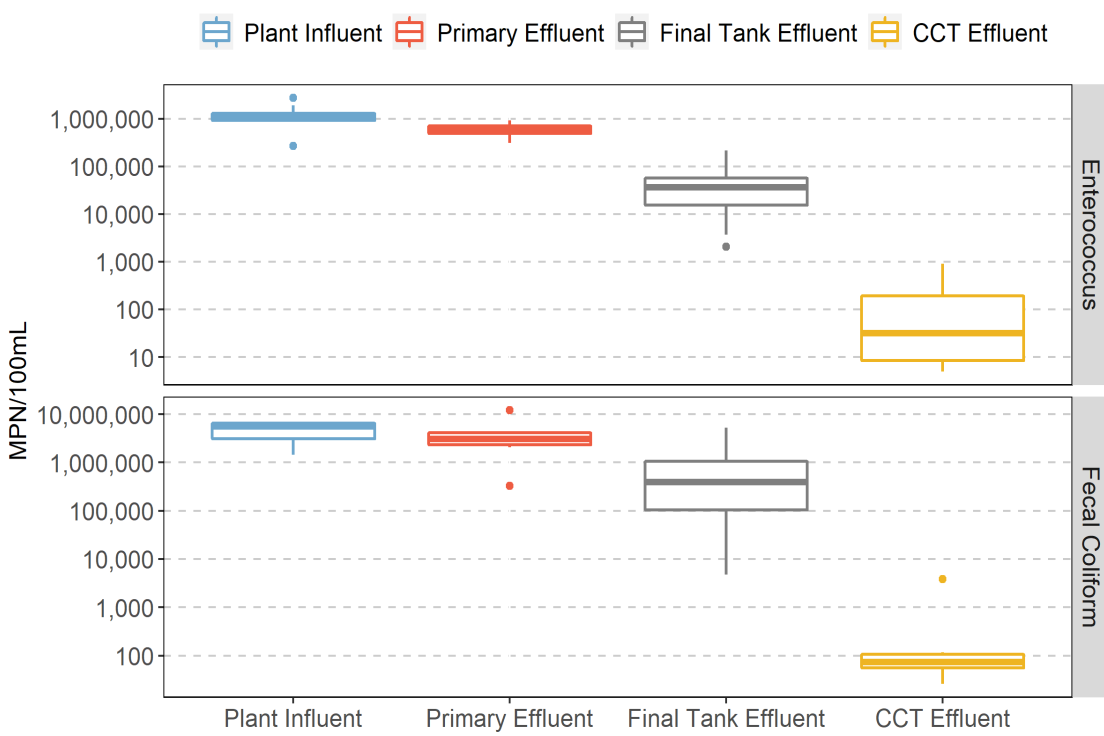


Figure 2-4 Port Richmond Bacterial Concentration Distributions by Location

Throughout the 12-day sampling period, the influent bacterial concentrations to the facility were consistent, except for the first day of sampling when the enterococcus concentration reached 2.68 x10^5 MPN/100mL. No significant reduction in bacterial concentrations resulted from primary treatment (red and blue dots).

The reduction in bacterial concentrations across secondary treatment varied during this sampling program, such that concentration in the CCT influent varied by more than two orders of magnitude, with CCT influent enterococcus between 10^3 – 10^5 MPN/100mL and CCT influent fecal coliform between 10^4 – 10^6. Such variability can significantly impact disinfection performance, requiring a higher residual in order to maintain the desired log reduction for the maximum bacterial concentration. **Table 2-8** presents summary statistics of CCT influent and effluent bacterial concentrations. For reference, historical bacterial concentrations are also presented from Port Richmond's DMRs.

Table 2-8 Summary Statistics of Port Richmond Bacterial Concentrations

Parameter	Final Tank Effluent Enterococcus (MPN/100mL)	Final Tank Effluent Coliform (MPN/100mL)	CCT Effluent Enterococcus (MPN/100mL)	CCT Effluent Fecal Coliform (MPN/100mL)
	[Historical 3/1/2016 – 4/30/2020] (Sampling Program 6/29/2020 – 7/17/2020)			
Sample Count	NA/12	NA/7	38/12	1,159/7
Min	NA/2,875	NA/10,300	1/5	1/26
2nd Percentile	NA/3,926	NA/18,406	1/5	2/28
Geomean	NA/29,582	NA/330,504	4/36	45/114
98^{th} Percentile	NA/139,384	NA/2,588,280	473/761	1,297/3,402
Max	217,600	2,758,500	1020/910	4,000/3,850

[1] –The first value represents historical data and the second value represents 2020 sampling program statistics

2.5.3.2 TRC, cBOD and TSS Results

Results for TRC, cBOD and TSS are presented on **Figure 2-5** as a time series plot throughout the sampling program duration. **Figure 2-6** shows the distribution of this data at each sampling location. Chlorine residual was measured at each location using the Hach DR2800. However, high turbidity and color can lead to inaccuracy in the results from the DPD method, as well as the presence of other oxidizing agents. This is the suspected explanation for the Hach DR2800 instrument measuring chlorine residual in the plant influent. This high strength wastewater is expected to have no chlorine residual. Chlorine residual is more likely to occur downstream of the plant influent where chlorinated RAS may be recycled.

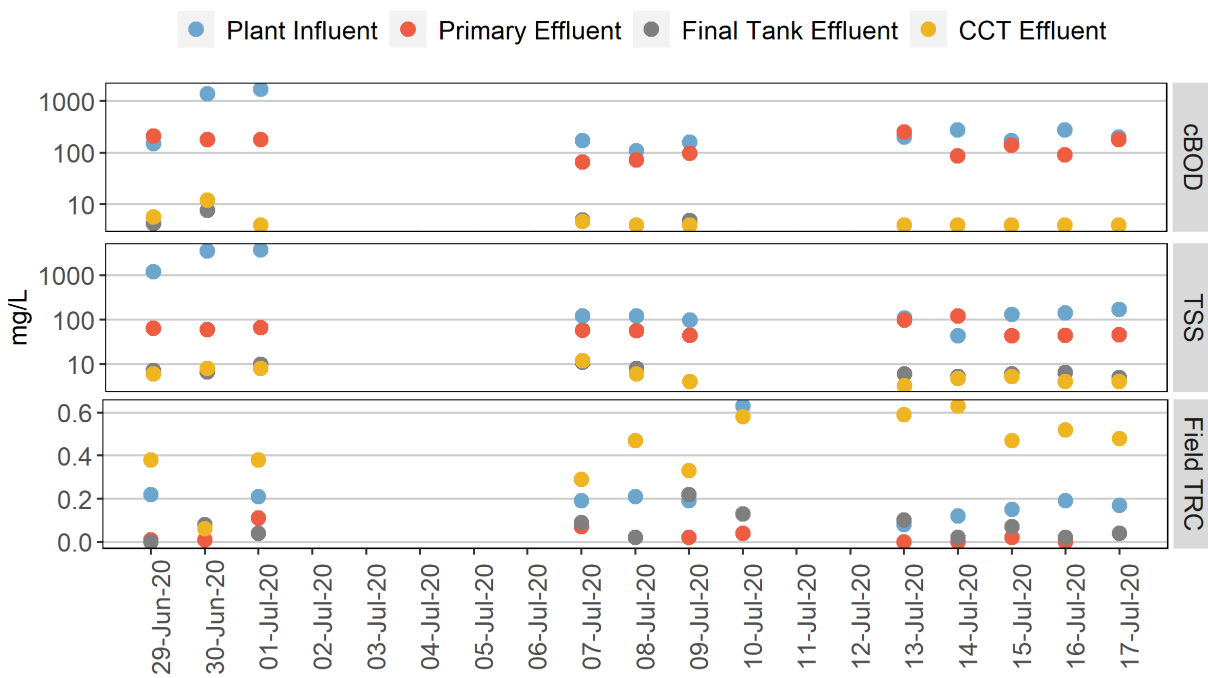


Figure 2-5 Port Richmond cBOD, TSS, and TRC Concentrations Sampling Time Series

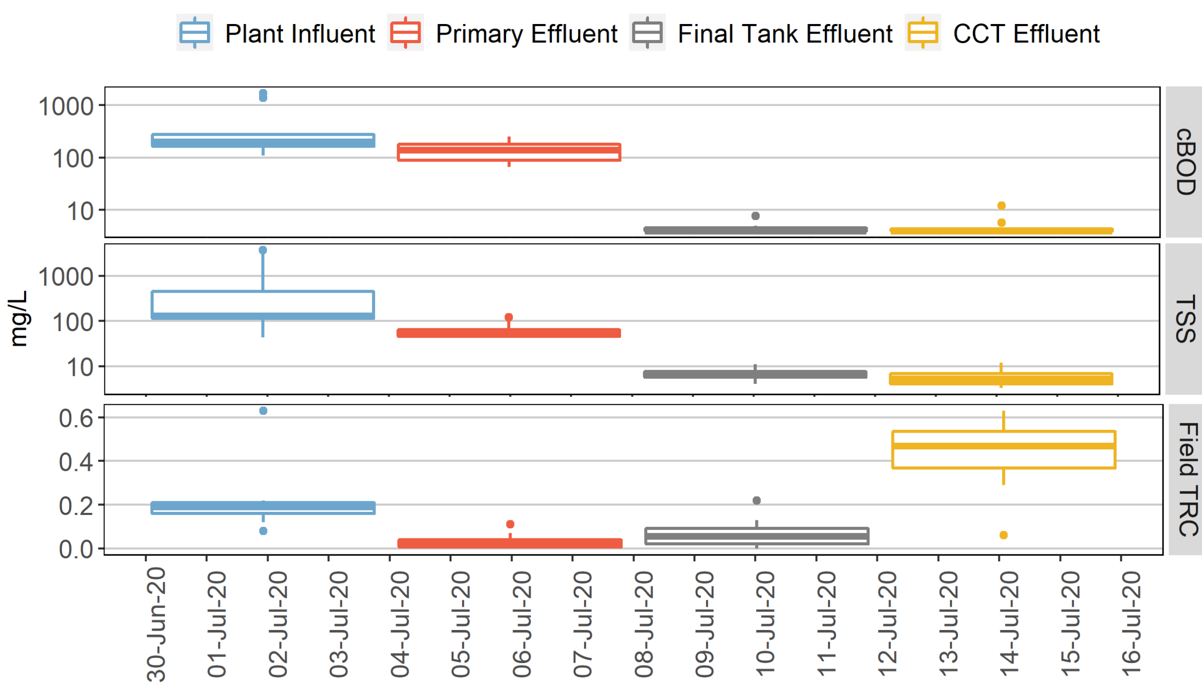


Figure 2-6 Port Richmond cBOD, TSS, and TRC Concentrations by Location

During the first three days of sampling, both influent cBOD and TSS exceeded 1,000 mg/L. Two extremely high influent TSS samples were observed on the second and third day of sampling with influent measurements of 3,500 mg/L and 4,000 mg/L respectively. As shown in **Table 2-9**, historically, Port Richmond has never reported a daily average value this high, however the DMR data provides daily average composite samples while the sampling program is based on a single grab sample. (Port Richmond AT sheets did report an influent TSS concentration of 1,543 mg/L on July 20th, after this characterization program had been completed.) The cBOD values for that day were high as well possibly due to the particulate fraction from a high TSS sample.

The June and July Pratt Paper **Daily Effluent Analysis** provided TSS and cBOD concentrations and loads for six days during June and four days during July, none of which coincided with the June 29th through July 1st sampling period when the high TSS and cBOD concentrations were measured in the influent grab samples. The reported average cBOD concentrations for the months of June and July exceeded 6,000 mg/L. The reported average TSS concentrations were 60 and 66 mg/L for June and July respectively, both considerably lower than the observed influent TSS concentrations at the plant.

Pratt Paper's reported average daily cBOD load for July was 30,498 lbs/day, while Port Richmond reported an average daily cBOD load of 71,681 lbs/day. However, on July 15th, both Port Richmond and Pratt Paper reported influent CBOD loads; on that day the reported Pratt Paper cBOD load was 27,759 lbs/day, while the reported Port Richmond load was 13,894 lbs/day (see Process sheet, cBOD influent loading). This discrepancy is presumably attributed to different sampling times, but indicates that Pratt Paper likely comprised most of the cBOD loading to the plant on that day.

The distribution of effluent TRCs throughout the sampling program was consistent with observations recorded historically in the DMRs – both with a mean residual of 0.43 mg/L.

Table 2-9 Summary Statistics of Port Richmond cBOD, TSS, and TRC Concentrations

Parameter	Influent CBOD (mg/L)	Influent TSS (mg/L)	Effluent CBOD (mg/L)	Effluent TSS (mg/L)	Effluent TRC (mg/L)
	[Historical 3/1/2016 – 4/30/2020] (Sampling Program 6/29/2020 – 7/17/2020)				
Sample Count	1,160/11	1,160/11	1,160/11	2,298/11	1,16012
Min	57.0/110	59/43	0.0/4.0	1.0/3.3	0.30/0.06
2nd Percentile	137/118	81/54	3.0/4.0	2.5/3.4	0.34/0.11
Mean	331/438	170/843	9.5/4.9	8.2/5.9	0.43/0.43
98th Percentile	610/1,640	388/3,660	34.8/10.7	35.1/11.2	0.65/0.62
Max	1,698,/1,700	2,000/3,700	132.0/12.0	166.0/12.0	1.18/0.63

[1] –The first value represents historical data and the second value represents 2020 sampling program statistics

[2] – Historical values are daily average composites while sampling program is based on one discrete sample per day

2.5.3.3 Chlorine Demand Testing

Variability in treated wastewater quality can impact the chlorine demand, resulting in corresponding variability in the required chlorine dose necessary to maintain bacteria inactivation.

Conversely, if the applied chlorine dose is maintained high enough at a fixed dose to account for the maximum demand, then the variability in demand will result in a proportional variation in the effluent residual. While for wastewater effluents, ammonia and nitrite have the greatest impact on chlorine demand, other organics, and some inorganics (e.g., hydrogen sulfide, ferrous iron, and manganese) can also impact the chlorine demand if they are present. Other factors affecting chlorine demand include temperature, pH, bacterial concentrations, and disinfection dose. Variability in factors that affect this demand can lead to complications in fine-tuning chlorine residual concentrations and resulting overdosing or underdosing. Port Richmond has several factors that can lead to variability in secondary effluent quality:

- Highly variable influent plant BOD loads affecting secondary treatment and causing inconsistent food to mass ratios, settling characteristics, and bulking in activated sludge;
- Variable CCT influent bacteria loads ranging between 10^4 – 10^6 MPN/100mL fecal coliform as observed throughout the sampling program; and
- Difficulty maintaining consistent dissolved oxygen levels throughout the aeration system leading to filamentous bacterial growth.

Two chlorine demand tests for this study were conducted on the 8th and 10th day of sampling. 5-gallons of final tank effluent were collected on each day and the demand tests were conducted at 20°±1°C. The study was conducted as follows (see **Appendix B** for the full chlorine demand procedure):

- Screening investigation – Dosing five chlorine doses between 0.5 and 3 mg/L based on historical dosing concentrations, and residual measurement are recorded after 5 minutes of contact time;
- Residual interpolation – Interpolating TRC results from screening evaluation to determine the chlorine doses required to achieve target residual concentrations of 0.2, 0.4, 0.6, 0.8 and 1 mg/L. These target residual concentrations were selected based on historical residual concentrations from the facility's DMRs, and
- True demand investigation – Conducting demand investigation using interpolated doses required to achieve desired chlorine residual concentrations. Residual is measured at 2 minutes of contact time to obtain initial demand and then at 30 minutes of contact time to emulate contact tank hydraulic residence times. This demand investigation is run twice to obtain duplicate results and ensure adequate QA/QC.

Results of the two chlorine demand tests are presented in **Table 2-10** and **Table 2-11**. Results confirm that the initial demand (2-minute contact time) consumes the majority of the chlorine. The resultant total residual chlorine after 30 minutes of contact time was expected based on the target residual. However, the dose to achieve the same target residual varied significantly between the two days and demand investigation 2 required an average 39% higher dose, indicative of the variable CCT influent quality. **Figure 2-7** and **Figure 2-8** show the demand difference between the two investigations. Influent bacterial concentrations of fecal coliforms during the sample day of investigations 1 and 2 were on the order of 10^3 and 10^4 MPN/100mL respectively.

2.5.3.4 Particle Size Distribution

Particle size distribution (PSD) can impact disinfection effectiveness by screening bacteria within the solids particle from the effects of the disinfectant, in this case chlorine. Studies have shown that effluents with larger PSDs, can require higher disinfectant dose or longer contact time in order to maintain the same level of inactivation as effluents with smaller PSDs. PSD analysis was conducted at Particle Technology Labs using Single Particle Optical Sensing (SPOS) technology. This analysis was conducted on two separate sampling days on aeration tank effluent. PSD provides information on solids size distributions which can give insight into bulking sludge or changes in solids sizes that may affect disinfection.

The distribution of solids sizes by % volume is presented in **Figure 2-9**. The results for the first particle size sampling event (July 13, day 8) shows a large fraction of particles between 20 and 200 µm with the distribution skewed heavily towards the larger particles in that range. This trend is consistent on the second particle size sampling event (July 15, day 10) as shown in **Figure 2-10**.

These results were compared to a PSD evaluation conducted in 2005; the results of the summer sampling event conducted July 2005 is presented in **Figure 2-11**. The 2005 distribution shows particle sizes ranging between 2.5 µm and 37.5 µm pointing towards a considerable increase in solids size over the past fifteen years, potentially resulting in wastewater that can become increasingly difficult to disinfect as the bacteria become entrained in the particles. The full particle size distribution report can be found in **Appendix B**.

2.5.3.5 Other Process Data

Table 2-12 presents additional plant data and operational metrics that were provided by the DEP during this sampling period which include plant flow, SVI, and MLSS. Historical data from Port Richmond's DMRs is also presented in **Table 2-12** for comparison. The facility was running at slightly lower flows and higher SVIs than typical. Average MLSS was running lower than typical for the facility which can affect secondary treatment performance and sludge quality.

Investigation 1 Screening	
Starting Temperature C	Starting pH
19	7.31
Chlorine Dose (mg/L)	**TRC - 5 min (mg/L)**
0.5	0.1
1	0.3
1.5	0.48
2	0.69
3	1.14

[redacted]

Table 2-10 - Demand Investigation 1 (mg/L)

7/13/2020	Target TRC	Chlorine Dose	TRC - 2 min	TRC - 30 min	Demand
Initial	0.2	0.75	0.2	0.19	0.56
	0.4	1.25	0.38	0.34	0.91
	0.6	1.75	0.6	0.54	1.21
	0.8	2.25	0.7	0.71	1.54
	1	2.75	0.94	0.92	1.83
Duplicate	0.2	0.75	0.2	0.12	0.63
	0.4	1.25	0.38	0.23	1.02
	0.6	1.75	0.6	0.52	1.23
	0.8	2.25	0.7	0.64	1.61
	1	2.75	0.94	0.83	1.92

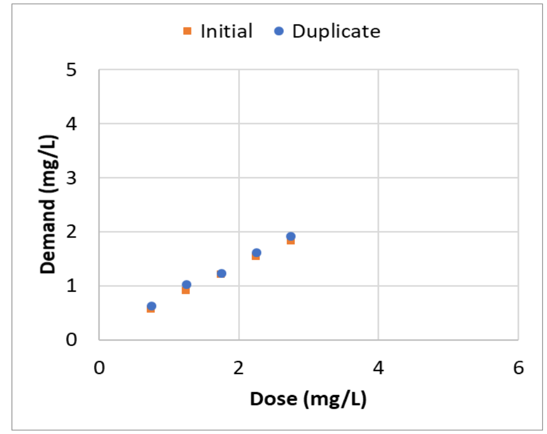


Figure 2-7 Investigation 1 Dose vs Demand

Investigation 2 Screening	
Starting Temperature C	Starting pH
19	7.18
Chlorine Dose (mg/L)	**TRC - 5 min (mg/L)**
0.5	0.12
1	0.17
1.5	0.29
2	0.42
3	0.51

[redacted]

Table 2-11 Demand Investigation 2 (mg/L)

7/15/2020	Target TRC	Chlorine Dose	TRC - 2 min	TRC - 30 min	Demand
Initial	0.2	1	0.24	0.18	0.82
	0.4	2	0.4	0.32	1.68
	0.6	3	0.6	0.49	2.51
	0.8	4	0.91	0.73	3.27
	1	5	3.73	1.06	3.94
Duplicate	0.2	1	0.24	0.17	0.83
	0.4	2	0.36	0.3	1.7
	0.6	3	0.56	0.42	2.58
	0.8	4	0.9	0.71	3.29
	1	5	3.92	0.92	4.08

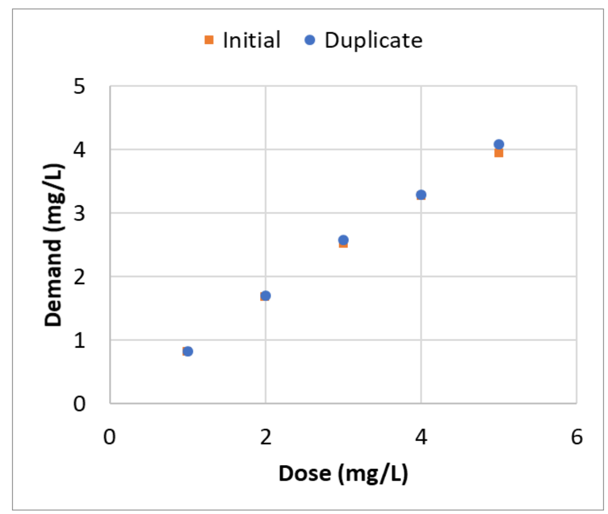


Figure 2-8 Investigation 2 Dose vs Demand

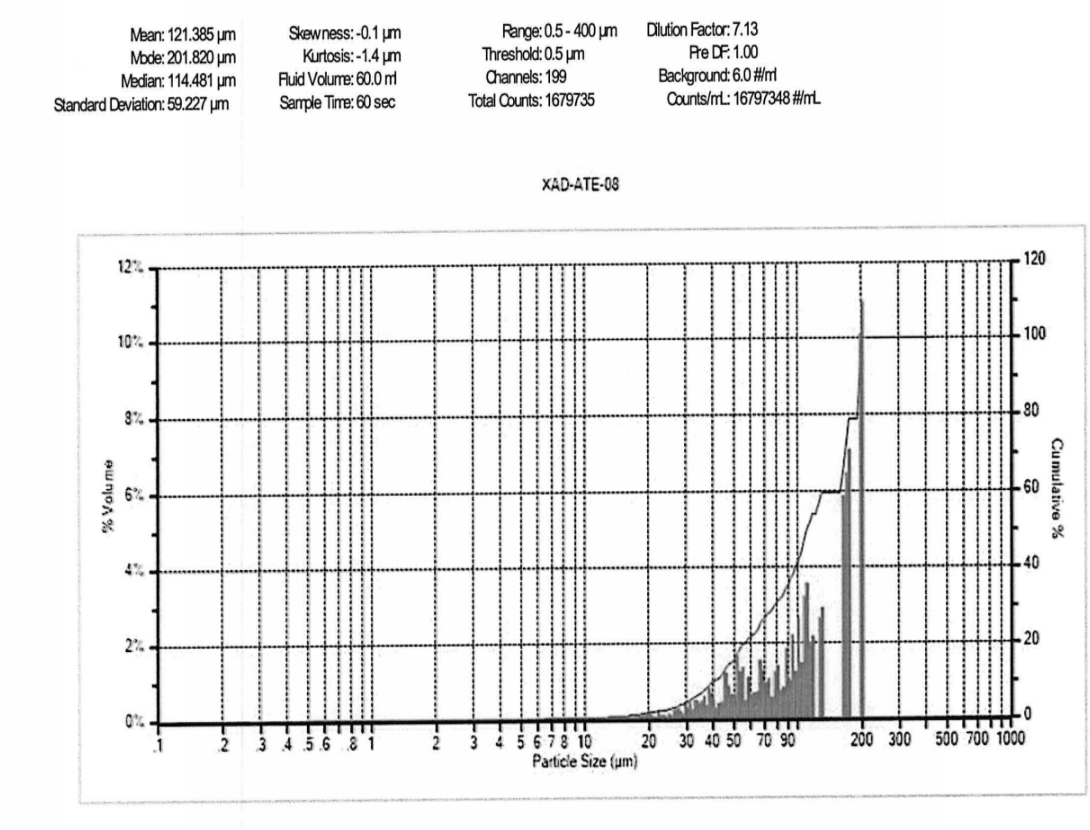


Figure 2-9 Particle Size Distribution by Volume for Day 8 of 12

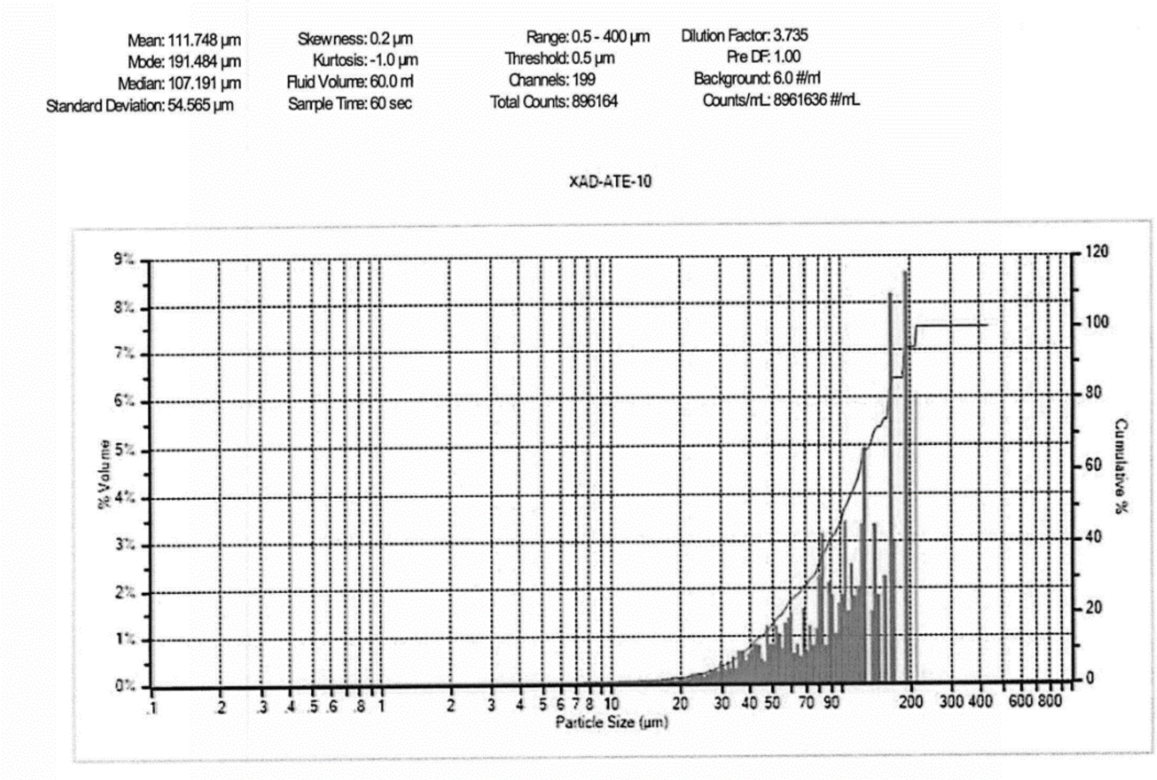


Figure 2-10 Particle Size Distribution by Volume for Day 10 of 12

Table 2-12 Additional DEP Operational Data

Parameter	SVI	Aeration Tank MLSS (lb/d)	Flow (MGD)
	[Historical 3/1/2016 – 4/30/2020] (Sampling Program 6/29/2020 – 7/17/2020)		
Sample Count	655/12	657/12	1160/12
Min	40/7	475/560	15.0/18.0
2nd Percentile	50/84	625/584	18.0/18.2
Mean	175/228	1,300/840	26.9/21.8
98th Percentile	460/415	2,604/1,140	57.0/29.9
Max	690/423	3,330/1,160	95.0/31.0

[1] –[1] –The first value represents historical data and the second value represents 2020 sampling program statistics

2.5.4 Sampling Program Conclusions

The wastewater characterization sampling resulted in the following observations and conclusions:

- Influent bacterial concentrations and primary treatment were relatively consistent.

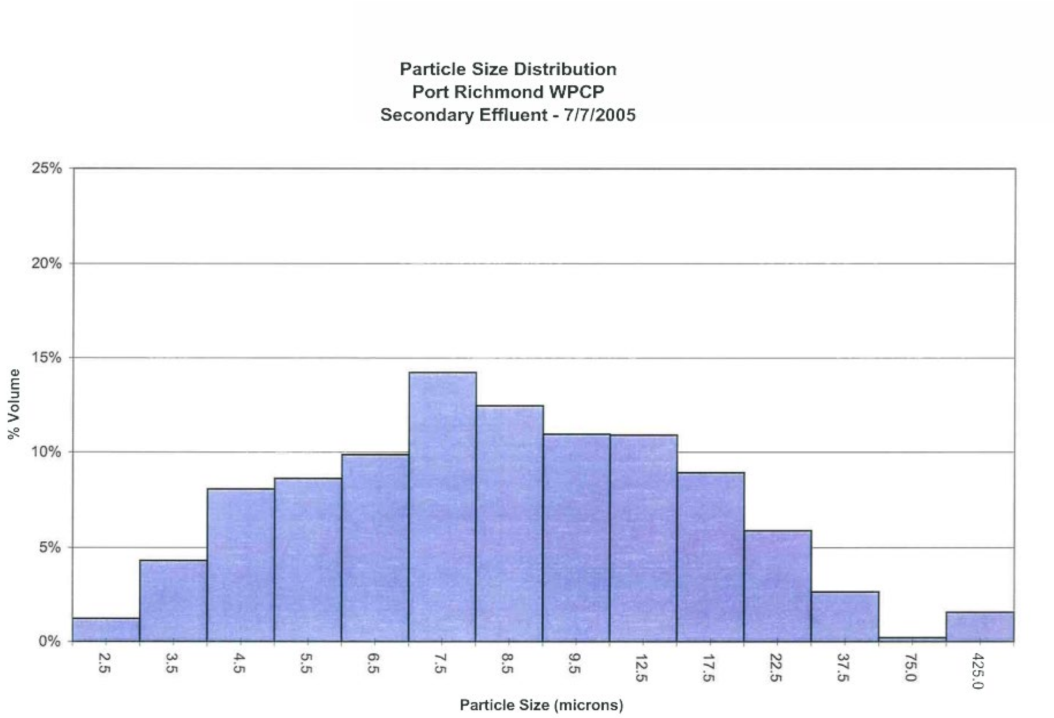


Figure 2-11 July 2005 Particle Size Distribution Results

- Reduction of pathogen indicators across the secondary process is not consistent resulting in CCT influent concentrations that vary over two orders of magnitude.
- CBOD and TSS loading to the plant were significantly higher than typical sanitary wastewater (both exceeding 1,000 mg/L) on three of the days sampled. The plant reported heavy foaming and filamentous bacteria growth on those days, leading to high RAS chlorination.

- The plant seems to consider the impact of RAS chlorination when identifying target doses for disinfection.
- The particle size distribution results indicate a significant increase in solids sizes since 2005.

Section 3

Data Evaluation

Each of the following factors that could potentially impact the chlorination process was evaluated using available data, as described in more detail below:

- Precipitation/Wet Weather events
- Process control challenges
- Discharge from Pratt/Visy Paper
- Variation in chlorine demand (based on influent wastewater characteristics and/or upstream process effectiveness)
- Return Activated Sludge (RAS)/Waste Activated Sludge (WAS) chlorination

Sodium hypochlorite use (e.g., age and strength)Data provided from BWT for the period from January 2014 through April 2019 was used to explore potential impacts from each of these factors. Effluent fecal coliform for the period of interest are shown on **Figure 3-1** and days where chlorine was exceeded are highlighted red.

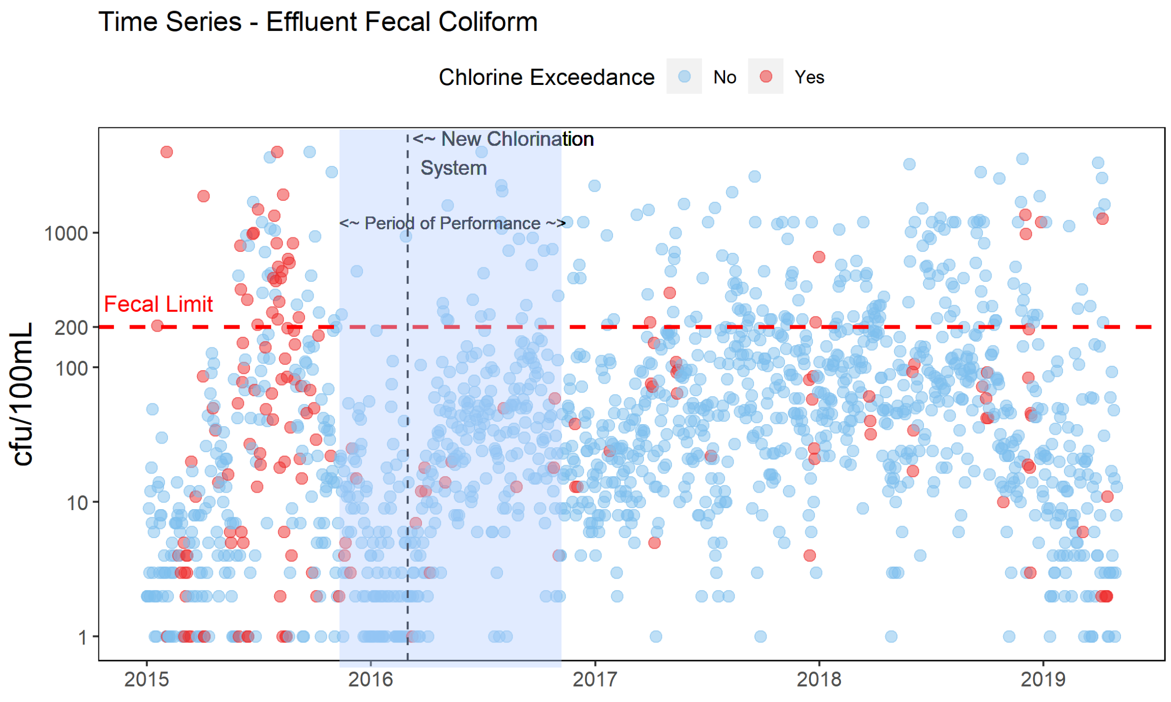


Figure 3-1 Effluent Fecal Coliform from 2015 through April 2019

The AT sheets, PLC data and process control logs were all reviewed for 21of the periods of high TRC after the new chlorination system was implemented in an effort to identify the underlying driving factors, as described below.

3.1 Precipitation/Wet Weather Events

Based on review of the twenty-one time periods of elevated effluent TRC that were evaluated in detail, ten (nearly half) of the events occurred on days where the plant reported precipitation. Wet weather coinciding with elevated effluent TRC is indicated on **Figure 3-2**. The dots indicate daily precipitation reported in inches, dots that are red indicate that TRC exceeded 0.52 mg/L and the blue dots indicate that TRC was below 0.52 mg/L. The figure also shows however, that elevated TRC also occurred with no precipitation impacts.

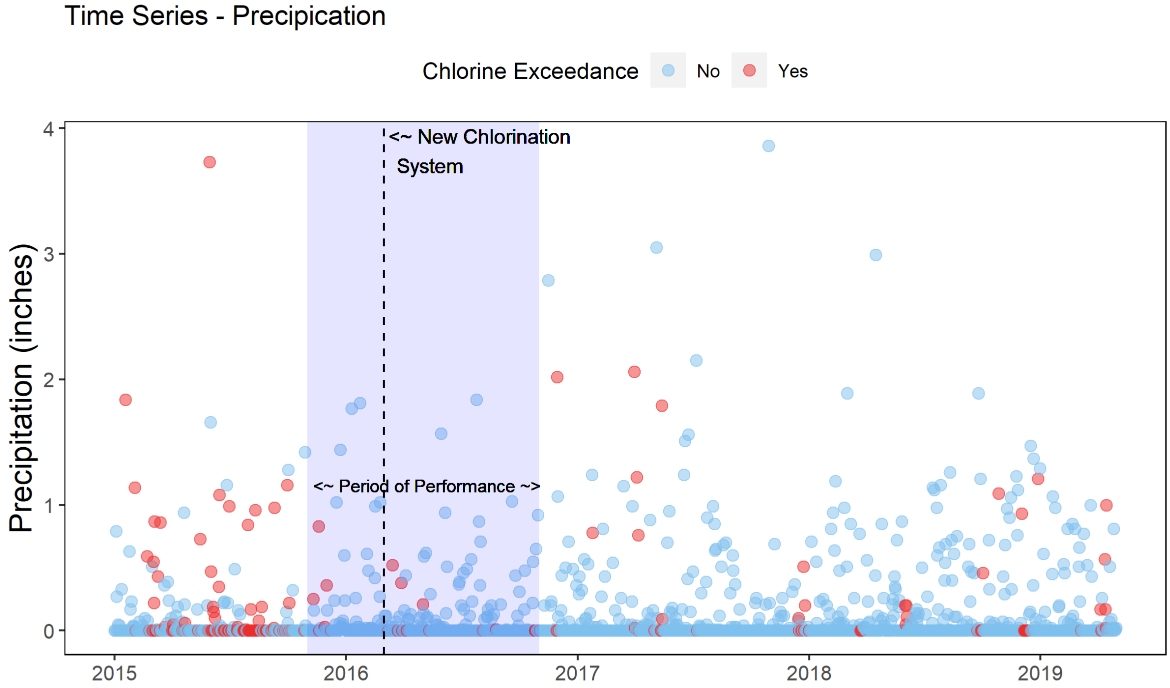
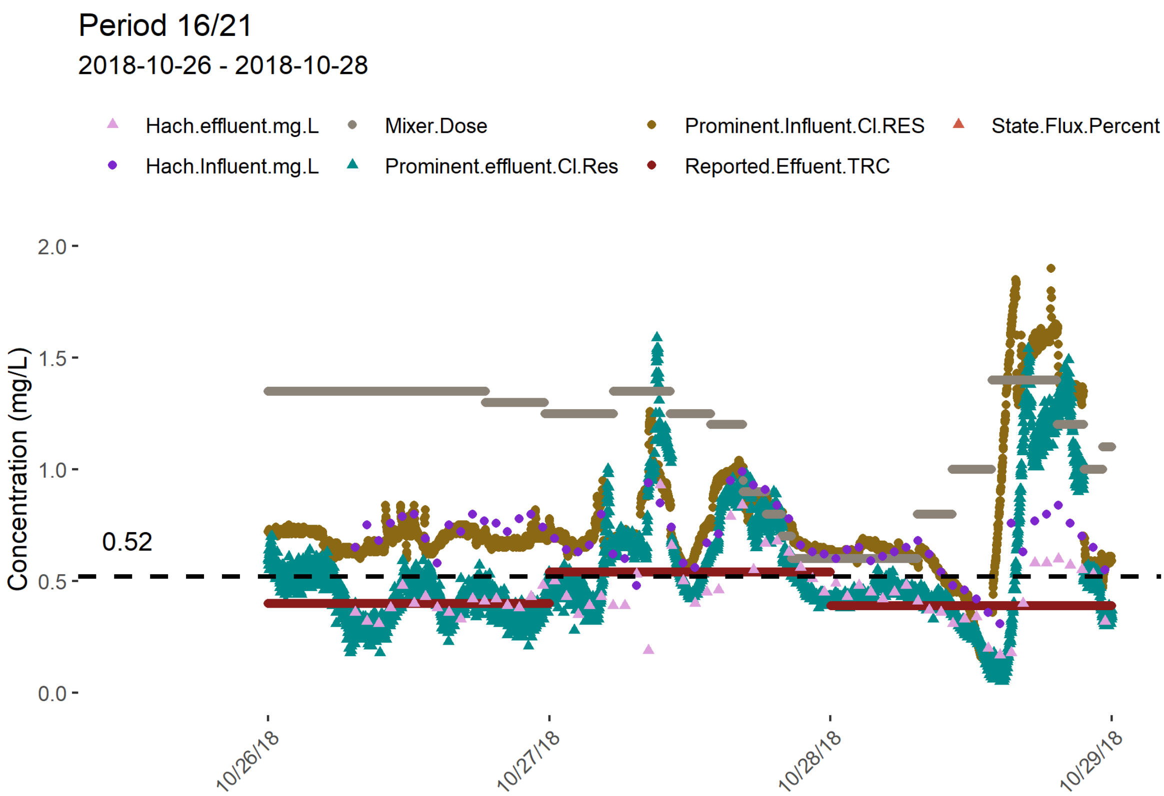


Figure 3-2 Precipitation and TRC

More detailed view of the process control sheets and PLC data were helpful in identifying the reasons for the elevated TRC levels during precipitation events. Data collected during two of the events is illustrated by **Figure 3-3**.

Both panels include the assigned mixer sodium hypochlorite dose (gray line), influent TRC as measured by the Hach analyzer (purple circle) and Prominent analyzer (brown circle), effluent TRC measured by the Hach (pink triangle) and Prominent (turquoise triangles) analyzers and the reported hourly TRC (burgundy line). Solids flux is also presented as orange triangles (only shown for the 12/20/2018 event in the lower panel).



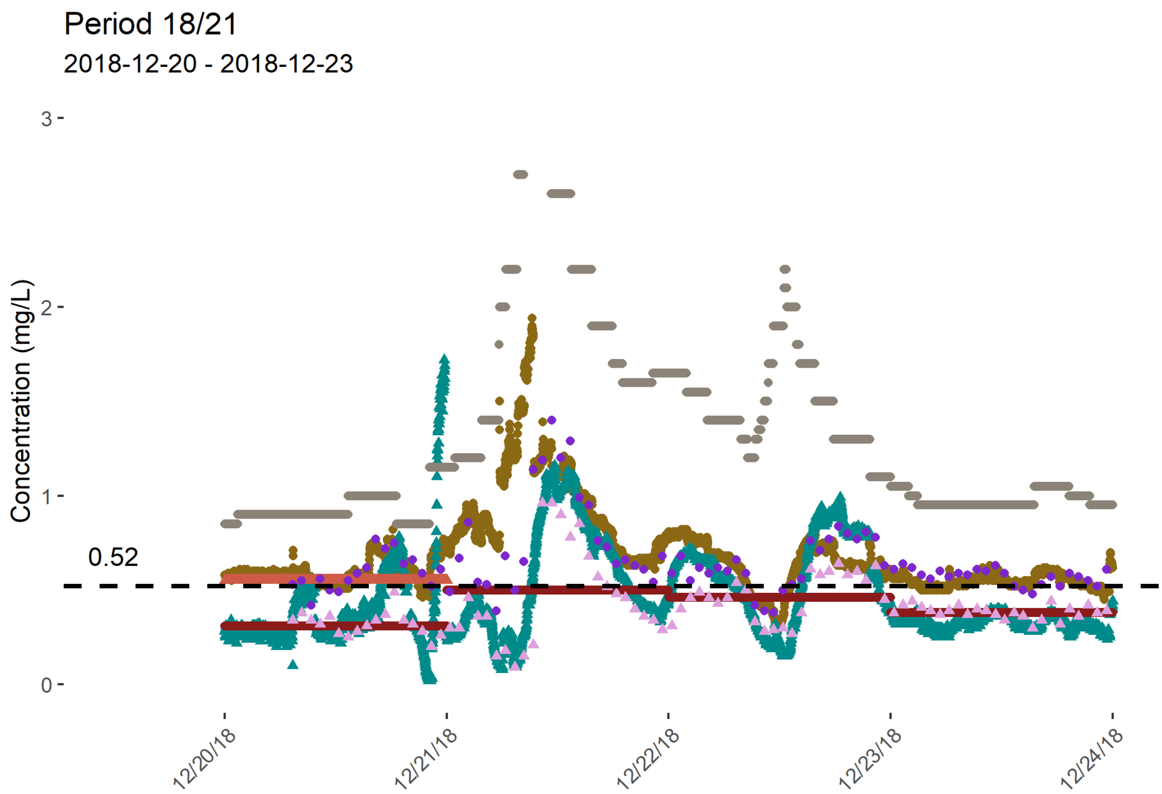


Figure 3-3 Reported Influent and Effluent TRC Concentrations during October and December 2018 Storm Event

Review of the operator notes during the precipitation events revealed that during some precipitation events, the chlorine dose was proactively increased to address anticipated impacts from the wet weather. During the TRC exceedance beginning November 24, 2018, the effluent target was set at 0.50 mg/L to 0.60 mg/L to achieve disinfection.

These exceedances are attributed to storm flows on November 24 and 26, 2018, which washed out solids and resulted in low aeration solids concentrations. As a result of the heavy wet weather flows on December 1 and 2, 2018, the plant was inundated with grease and oil causing a bloom of M. Parvicella (a grease and oil filament). Between December 1 and 2, 2018, the sewage temperature dropped from 16°C to 12°C which further shocked the biology causing poor settleability. Finally, Final Settling Tank No. 3 was taken out of service for flight maintenance from November 27 to December 12, 2018, thereby reducing the surface overflow rate and detention time in the final settling tanks. The sudden temperature change, heavy influx of M. Parvicella, and decreased final settling time caused solids to remain in suspension and inhibited the increase of solids inventory. A high dose of sodium hypochlorite was sent to RAS and wasting was adjusted to increase solids inventory**.**

3.3 Process Control Challenges

Control of the chlorination process was identified as another potential factor during the observed elevated TRC intervals. The process control challenges were also observed during some of the precipitation events with high effluent TRC. For example, during the precipitation event highlighted in **Figure 3-3**, the process control sheets also reported that heavy solids were observed and the effluent TRC probe would not hold calibration.

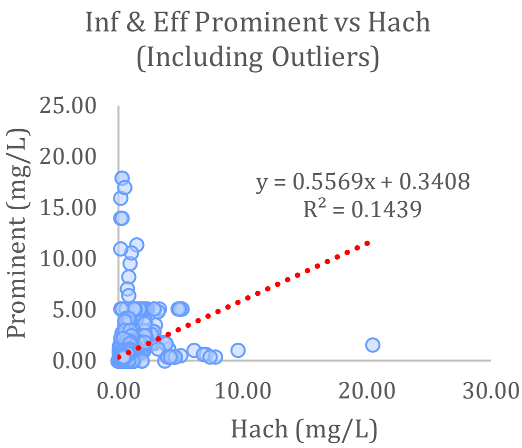
The Port Richmond disinfection system was upgraded in 2016 and has been working well according to the Operating staff with the following exceptions:

- Prominent probes are not calibrated and are cleaned monthly. Because they cannot be used as part of the automated system, the ability to respond quickly to changing conditions is reduced.
- A hydraulic bottleneck downstream of the Parshall flume results in surcharging of the flume during high flow events. As a result, the automatic dose pacing control currently uses the plant influent flow to calculate the hypochlorite feed rate, which can result in underfeeding/overfeeding due to the lag time between changes in influent and effluent flow. DEP is in the process of modifying the controls to provide more accurate effluent flow monitoring even during surcharged conditions.
- The CCTs have reportedly not been cleaned since 2015 – 2016 when the new chlorination system was being installed. This can impact the available volume for disinfection reducing actual contact time and can also result in the resuspension of solids during high flow events.
- The high range pumps were not turning on fully during wet weather. DEP was looking to trouble-shoot this issue with the manufacturer during a significant rain event.

Use of the emergency drip was noted during seven of the 20 TRC exceedance intervals evaluated. A higher diffuser dose was reported during three of the 20 TRC exceedance intervals, because the mixer was reportedly not achieving the effluent target dose.

Because the Prominent probes have been observed to drift, and they are not maintained on daily basis, the plant could not rely on the automated system to control the chlorination process. The chlorine measurements reported by the Hach benchtop DPD analysis were compared to the chlorine measurements reported by the Prominent analyzers to assess reliability and differences. The data was filtered based on an outlier statistical approach of removing data with z-scores (standard score defining how many standard deviations a value is from the mean of the distribution) outside of the boundary between -3 and 3. This assumes data follows a gaussian distribution and maintains 99.7% of the dataset.

Figure 3-4 shows the relationship between the measurements from the two instruments with and without outliers included. The regression coefficients show that there is a strong relationship between the Hach analyzers and the Prominent analyzers with an R^2 of 0.69. The relationship was stronger on influent recorded data than effluent recorded data likely due to the tendency of the effluent Prominent probe to drift towards 0 mg/L over time. The slope of the line (without outliers) suggests that the Hach probe tends to measure chlorine at slightly greater concentrations which may be attributed to the Prominent probe's drifting characteristics. The regression summary is provided in **Table 3-1** and all regression coefficients were statistically significant (p-value < 0.05).



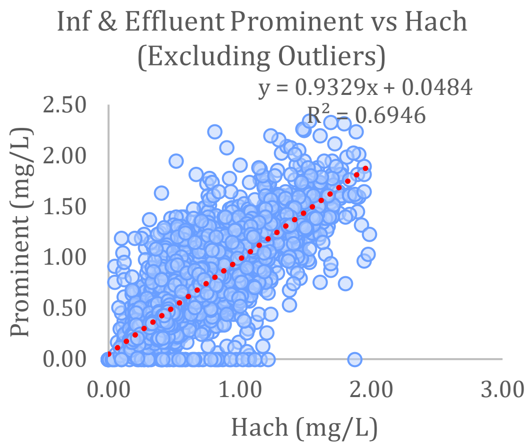


Figure 3-4 Comparison of Hach and Prominent Chlorine Measurements

Table 3-1 Comparison of Hach and Prominent Chlorine Measurements

Data Summarized	With Outliers		Without Outliers	
	Coefficient of Determination (R^2)	Slope	Coefficient of Determination (R^2)	Slope
Influent and Effluent Probe Data	0.14	0.56	0.69	0.93
Effluent Probe Data Only	0.04	0.49	0.47	0.83
Influent Probe Data Only	0.02	0.48	0.91	0.62

3.4 Discharge from Visy Paper

Port Richmond noted potential filamentous growth at their facility on several occasions when also receiving Visy Paper discharges, and this may be by a product of process upsets in secondary treatment process upsets. Several causative factors may be insufficient dissolved oxygen, temperature, pH, and food balance (carbon:nitrogen:phosphorus), and carbon source. **Figure 3-5** shows that Visy Paper comprises a significant percentage of the cBOD entering Port Richmond where the majority of the time the ratio is between 37-57 percent. With such a large portion of the cBOD coming from Visy Paper, the environment in Port Richmond's waste activated sludge process can speciate bacteria that are preferential to that substrate. It is not known whether the Pratt Paper discharge is consistently released over 24 hours, or if it is released to the Port Richmond plant in batches. If the Pratt Paper discharge is released to Port Richmond in batches, or over a single shift, the impact of the high strength waste will be even more significant during that duration. When the plant received wastewater of inconsistent strength, bacteria will be challenged to acclimate to constant change and this can result in filamentous growth and bulking sludge.

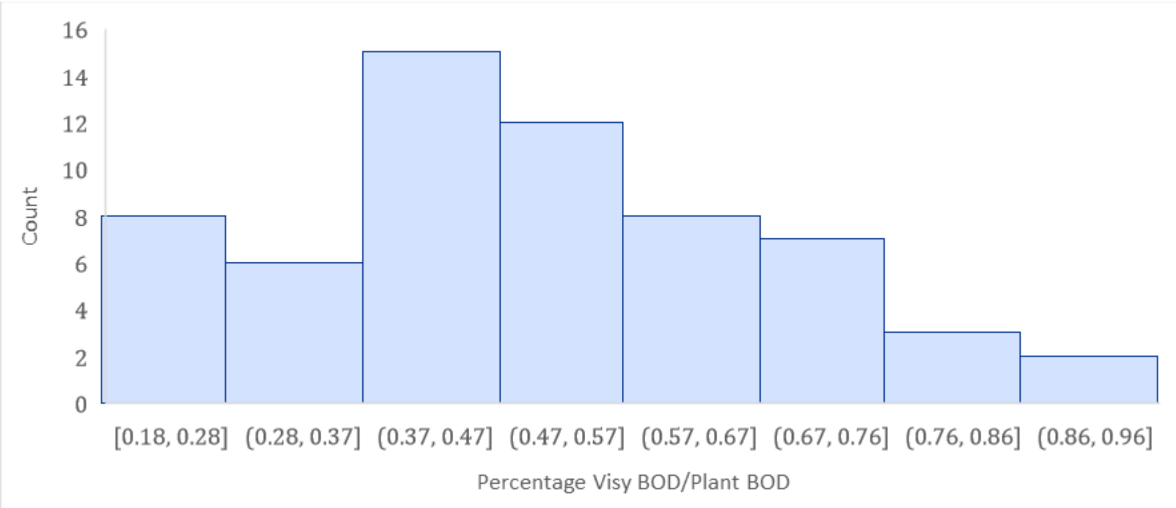


Figure 3-5 Percentage of Port Richmond BOD Load from Visy Paper

3.5 Variation in Chlorine Demand

The potential for variable wastewater quality to impact chlorine demand and effluent residual was evaluated by implementation of the June/July 2019 field sampling program described in Section 2.5. Wastewater quality throughout the process train was evaluated based upon samples collected:

- At the influent;
- After primary settling/upstream of aeration;
- After settling in the final tanks;
- From the CCT effluent.

The sampling results showed that levels of pathogen indicator organisms measured in the influent wastewater samples were generally consistent, at high 10^6 MPN/100 mL for fecal coliform and 10^6 MPN/100 mL (except for one day when the influent concentration was an order of magnitude lower) for enterococcus. Concentrations leaving the primary settling tanks/entering secondary treatment were generally lower for enterococcus at 10^5 MPN/100 mL and varied between 10^5 and 10^7 for fecal coliform. The data suggested that variability in secondary treatment may have an impact on disinfection as the concentrations of fecal coliform exiting the final clarifiers varied by three orders of magnitude (10^3 to 10^6) and concentrations of enterococcus varied by two orders of magnitude (10^3 to 10^5).

The chlorine demand testing conducted on two days of sampling also indicated the variability of CCT influent wastewater quality; the chlorine dose required to achieve an effluent target of 0.4 mg/L was 1.25 mg/L on the first day of testing (0.91 mg/L demand) and approximately 2.0 mg/L on the second day of chlorine demand testing (1.7 mg/L demand with a resulting 0.3 mg/L residual).

3.6 Solids Flux

A clarifier state point analysis (SPA) was performed for Port Richmond based on the provided DMR data to assess whether the final settling tanks were stressed based on solids loading and settling capacity. The state is a graphical approach derived from solids flux theory. It takes into consideration mixed liquor concentrations, settling characteristics, available surface area for compaction, and recycled flow rates. **Figure 3-6** provides an explanation of the elements considered in a state point analysis. A clarifier is considered overloaded when the state point (intersection of overflow and underflow rate operating line) is above the settling flux curve, or when the underflow rate goes above the settling flux curve.

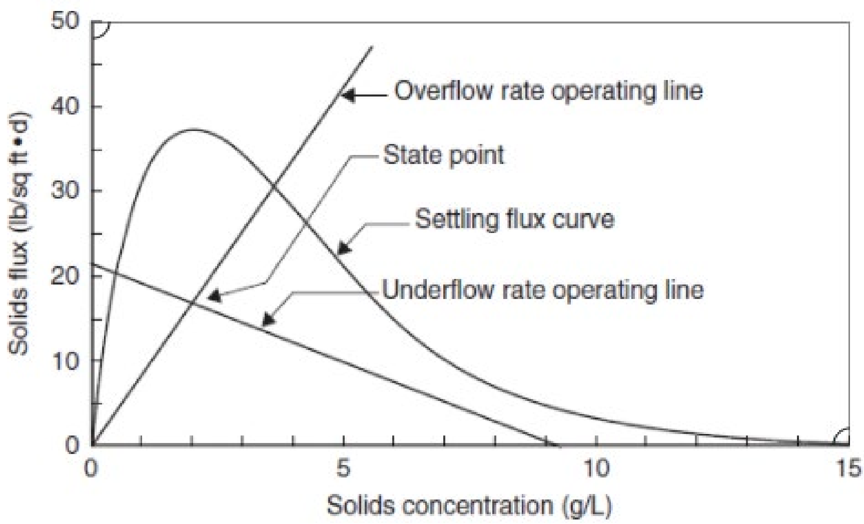


Figure 3-6 State Point Characteristic Curve

The theoretical settling flux capacity on each day was calculated for each day at Port Richmond with a 1.3 safety factor. **Figure 3-7** is a timeseries representing the ratio of the state point solids flux to the actual clarifier settling flux and clarifier overloading would occur on days this value is >1. The dots represent the ratio of state point solids flux and clarifier settling flux. On days where chlorine exceedances occurred the dots are highlighted in red to identify potential coincident events. The analysis showed that the facility generally does not have issues with clarifier capacity or solids removal. Two events where the settling flux was overloaded or critically loaded occurred prior to the chlorination system upgrade and both events exhibited chlorine exceedances on those days. Two additional observations of critically or overloaded clarifiers occurred after the chlorination upgrade, but these events did not have concurrently occurring TRC exceedances.

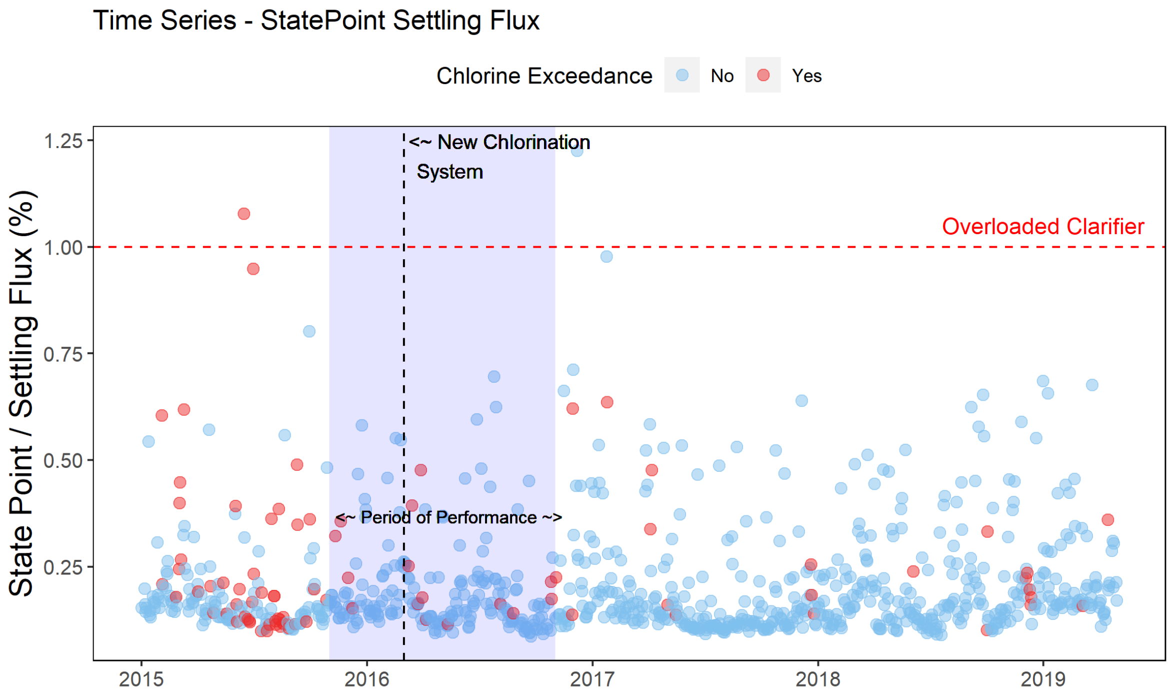


Figure 3-7 State Point / Settling Flux Over Time

3.7 RAS Chlorination

Return Activated Sludge (RAS) chlorination occurred during ten of the 20 periods of elevated TRC concentrations that were evaluated. It is not clear whether this results in higher than anticipated residual chlorine residual.

Review of the AT sheets for June and July 2020 suggested that the plant reduces the disinfection target during the days that RAS chlorination is occurring.

During the initial days of the sampling program, DEP maintained a residual target of 0.25 mg/L which is relatively low in comparison to the residual target 0f 0.4 mg/L identified in Port Richmond's historical daily monitoring reports. The residual target was increased to 0.35 mg/L on July 7th (the 4th sampling day) and then to 1 mg/L on July 10th (the 7th sampling day). This residual target increase is likely due to the relatively high effluent bacteria concentrations observed during the prior days. The residual target was reduced to 0.45 mg/L on July 13th (8th sampling day) where it remained for the duration of the sampling program.

Another chlorine application point at Port Richmond is within the return activated sludge (RAS). RAS is chlorinated to mitigate bulking sludge and filamentous organism growth that may be caused by poor aeration control. DEP has provided information on RAS chlorination and during the first four sampling days, the RAS chlorine dose was relatively high at 8.8 mg/L. This may explain why the TRC target was set lower than usual at 0.25 mg/L. The RAS chlorination dosage was reduced to 6.3 mg/L on the 4th day of sampling (and the chlorine residual target was increased to 0.35 mg/L) and then set to 0 mg/L on the 8th sampling day for the duration of the program.

3.8 Sodium Hypochlorite Use

The potential that variation in the strength of the sodium hypochlorite delivered to the CCTs could be contributing to effluent TRC variation was also considered by reviewing sodium hypochlorite use at the plant and comparison of deliveries to dates of elevated TRC. Port Richmond did receive sodium hypochlorite deliveries during eight of the 20 exceedance events, and switching hypo tanks was noted during 11 of the 20 events. Port Richmond has three 10,000 gallon bulk storage tanks and one 1,200 gallon emergency drip tank that will flow by gravity if there is a disruption to the chlorination system such as a power outage. On average, 5,000 gallon sodium hypochlorite (NaOCl) deliveries are made to the facility 3 to4 times per month. Deliveries occurred every 8 days on average, but there have been up to 49 days between deliveries.

The breakdown of hypochlorite deliveries from 2015 to 2019 are provided in **Table 3-2**.

Table 3-2 Port Richmond Chlorine Deliveries

Year	Average Deliveries Per Month	Total Deliveries
2015	3.67	44
2016	3.50	42
2017	3.42	41
2018	4.33	52
2019[1]	2.00	24

[1] – 2019 data from January 1st to April 30th

The hypo solution received at the facility is a 15 percent hypochlorite solution. Although this is the trade percentage, true available chlorine by % weight of this solution is approximately 12.4 percent and this is the most common strength used for disinfection applications with NaOCl. Chlorine half-life is estimated in **Figure 3-8** for three different trade percentages at different temperatures. Interpolating between 10% and 20% at a room temperature of 70 F, the half-life of the chlorine at Port Richmond is expected to be between 100 – 200 days. This can potentially result in increased use chlorine to meet the same dosing requirements. The DMRs indicate that tank 1 is the fill tank of choice and the three tanks are hydraulically connected with an equalization line.

The June and July 2020 AT sheets show that an average of 12,000 to 15,000 gallons of sodium hypochlorite was stored on-site during those months. During June 2020, 20,154 gallons were delivered to the Plant, 23,781 gallons were consumed (only 8,781 of this use was for disinfection) resulting in a reduction of 3,627 stored gallons over the month. During July 2020, 24,280 gallons of hypochlorite were delivered, 21,172 gallons were consumed (14,047 for disinfection), resulting in an increase of 3,648 gallons in hypochlorite storage.

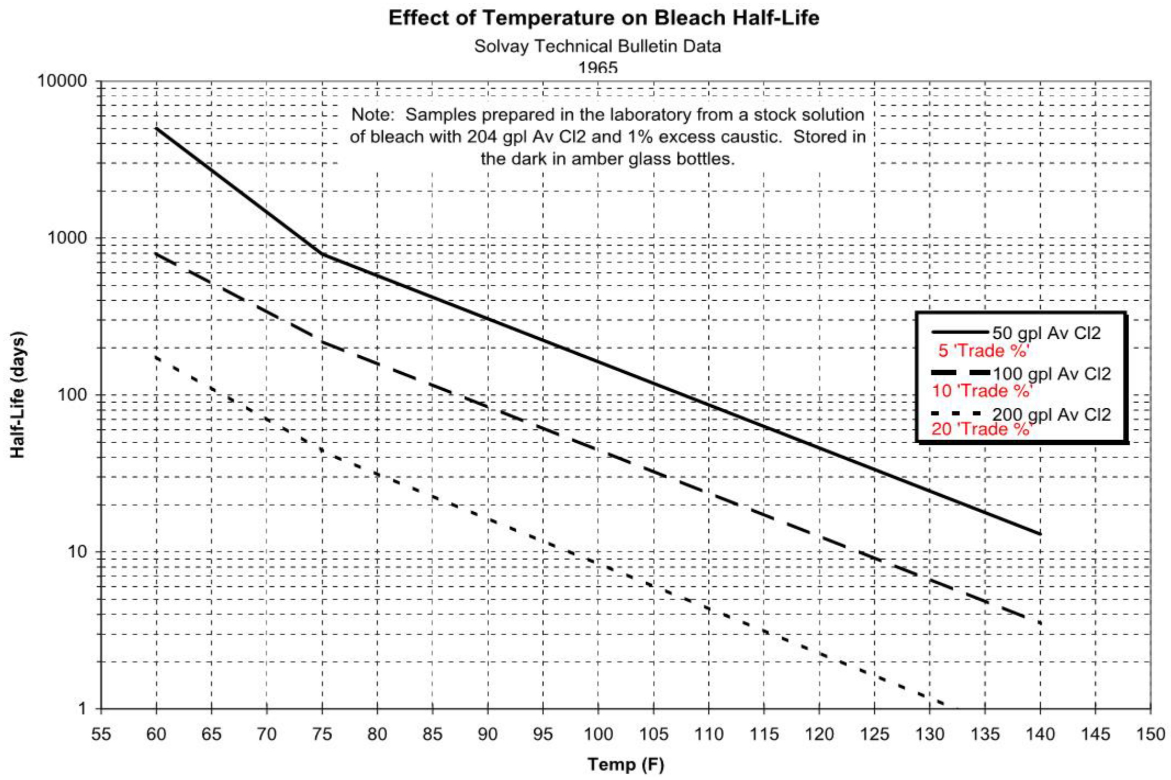


Figure 3-8 Chlorine Half-life

3.9 Data Evaluation Approach

In an effort to identify any measured wastewater quality or process parameters that may be impacting disinfection at Port Richmond, predictive statistical models were used to assess the relative importance of the different factors affecting chlorine exceedance amongst all of the potential factors identified. This involved

- Spearman correlations
- Support Vector Machine – Decision tree
- Logistic Regression
- Random Forest

Only data collected after the chlorination upgrade (3/1/2016) was used for the statistical analyses. Of the four methods, three were used as classification models to predict if Port Richmond would experience chlorine exceedances based on the data collected. The classifications shown in **Table 3-3.**

Table 3-3 Exceedance Event Proportions

Metric	Classification		Total
	Exceedance Event	Non-Exceedance	
Count	66	1090	1,156
Proportion	6%	94%	100%

When modeling data with a class imbalance of this nature (6% chlorine target exceeded:94% chlorine target compliance), models will typically provide results that accurately predict the majority class (non-exceedance events) but will fail to correctly classify exceedance events. In preparation for applying the classification models to the datasets, under sampling of the majority class was performed so that the models would not be skewed towards predicting non-exceedances, which resulted in sample sets with equivalent number of exceedances and non-exceedances. Cross-validation was performed on each model's datasets with bootstrap resampling to provide a measure of confidence on model accuracy. Of the three classification models, the random forest performed the best as shown in **Table 3-4.**

Table 3-4 Data Model Accuracies

Model	Accuracy	95% Confidence Interval
Baseline (No Model)	50%	44-56%
SVM Decision Tree	62%	53-70%
Random Forest	67%	60-73%
Logistic Regression	66%	59-72%

The Receiver Operating Characteristics (ROC) curve shown in **Figure 3-9** depicts the accuracy of each statistical model in comparison to the baseline of simply guessing if there will be a TRC exceedance event. All three statistical models performed better than guessing indicating that the underlying causes may be explained by the parameters considered at least part of the time. Sensitivity is a measure of the model's accuracy towards predicting true positives, and specificity measures model accuracy of predicting true negatives. The models were split into 75/25 (training/testing) datasets.

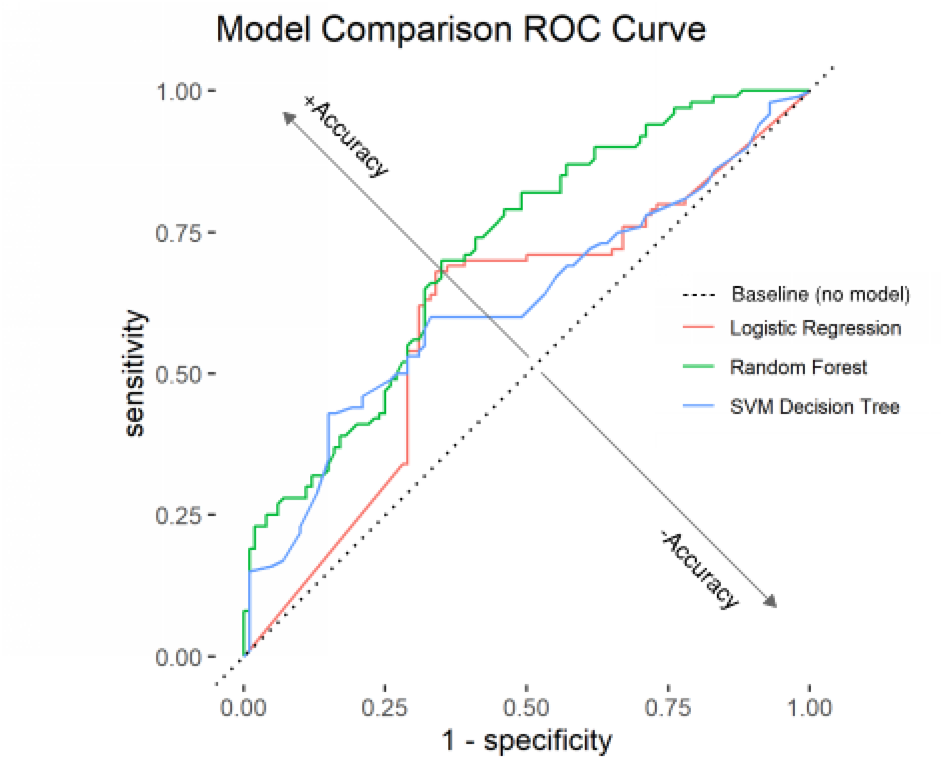


Figure 3-9 Model Receiver Operator Characteristic Curve Comparison

3.9.1 Statistical Evaluations

3.9.1.1 SVM Decision Tree

Decision trees are a supervised machine learning method used for classification and regression problems. This method operates by segmentation and aims to reduce the entropy of a dataset by continually splitting the data in a tree like structure by the most informative variables. An *example* decision tree from a subset of Port Richmond data is shown below where the root node (top most node) represents the best delimiter of the data and splitting continues down the tree until getting to the leaf nodes where the final classification is shown (exceedance, non-exceedance) the probability of that classification, and the percentage of the sampled data that remains in that leaf node.

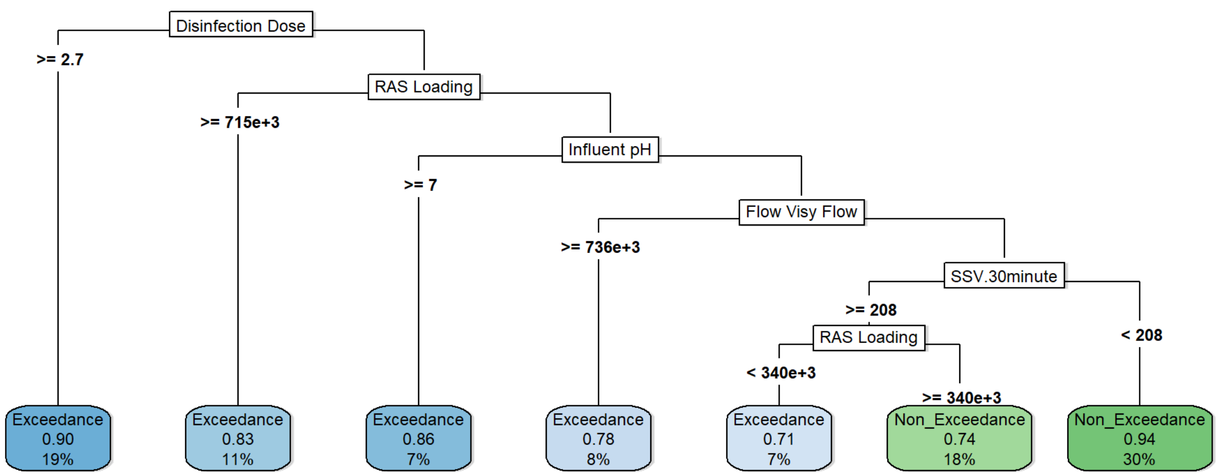


Figure 3- 10 Example Decision Tree on Subset of Port Richmond Data

[1] – Leaf node (bottom of tree) display predicted classification (exceedance/non-exceedance), probability that predicted classification is correct, and percentage of data from dataset used in in classification

The specifications for the decision tree can be found in **Table 3-5**. After running the model on cross-validation data under several random samples, the variable importance for the decision tree model was extracted and only the top 20 parameters are shown in **Figure 3-10.** The metric used to measure variable importance is a gini impurity reduction index where gini impurity is a measurement of how likely a variable will incorrectly classify a random sample. Disinfection dose, plant BOD loading, effluent TSS and flow were major predictors of chlorine exceedances and overall model accuracy in terms of correctly identifying whether a TRC sample would exceed the target of 0.52 mg/L measured 62% ± 8%.

Table 3-5 Decision Tree Model Configuration

SVM Decision Tree Specifications	
Type	Classification
Prediction	Chlorine Exceedance
Min observations required to split node	20
Min observations in terminal node	7
Cross-validation type	Monte-Carlo
Cross-validation computes	25
Max tree depth	30

3.9.1.2 Logistic Regression

Logistic regression in lieu of linear regression was used since our metric is a categorical classification (exceedance/non-exceedance event). This model measures the relationship between the dichotomized (binary classification) dependent variable (chlorine exceedance) by one or more predictor independent variables (e.g., wastewater quality or process measures) through a logistic function. An S-shaped sigmoid curve is fit to our observations determined by the equation:

$$Probablilty = \frac{1}{1+e^{-x1}} + \frac{1}{1+e^{-x2}} \ldots. + \frac{1}{1+e^{-xn}}$$

Where the probability determines the classification of the dependent variable (e.g., TRC > 0.52 mg/L) and where *x* represents the weighted sum of independent variable(s) used to make a prediction. An *example* logistic regression function is shown in **Figure 3-11** using just one predictor variable, disinfection dose where probabilities > 50% will predict TRC exceedances. The final model used all variables described in **Section 2.1** and creates a classification function where variable importance is shown side by side with the SVM decision tree and random forest in **Figure 3-12**. Variables/factors that affected whether or not TRC exceeded 0.52 mg/L include BOD, solids, and bacterial measures. This model maintained an accuracy measure of 66% ± 7%.

Table 3-6 Logistic Regression Model Configuration

Logistic Regression	
Type	Classification
Prediction	Chlorine Exceedance
Cross Validation Type	Monte-Carlo
cross-validation computes	25

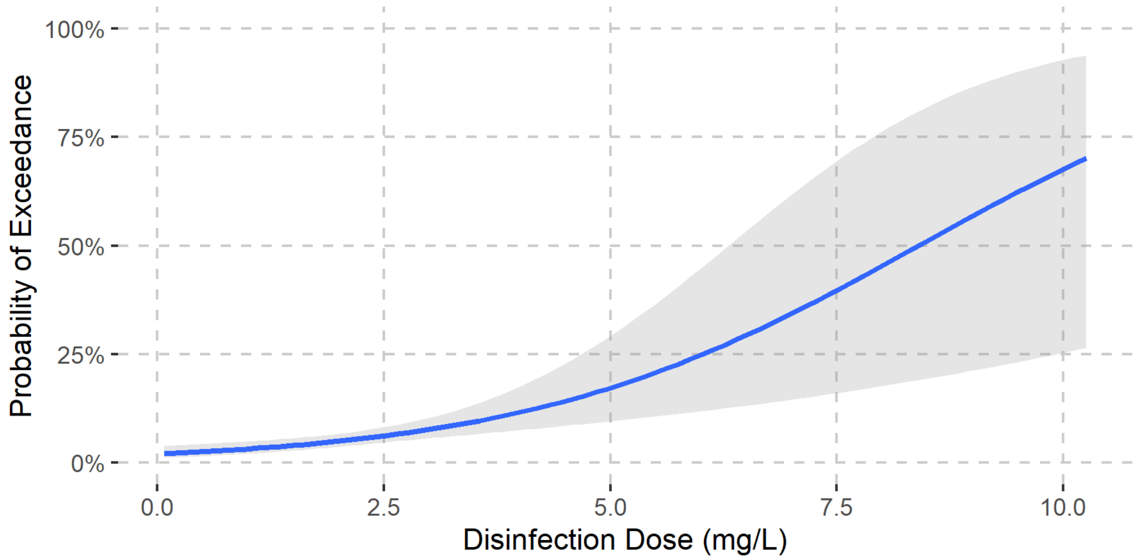


Figure 3-11 Sample Logistic Regression with Disinfection Dose as only Predictor Variable

3.9.1.3 Random Forest

A random forest is another supervised learning algorithm that combines the predictions of many smaller models to produce an aggregated prediction of whether or not TRC will exceed 0.52 mg/L. Specifically, a random forest is a collection of decision trees that each provide their own predictions, which are combined to produce a final prediction. Random forest models typically provide more accurate results than decision trees due to its ensemble structure and they are less susceptible to overfitting (predicting well on training data while predicting poorly on new data) Training data is defined as the subset of data used to develop the model and this is cross-validated with the remaining data that was used to train the models. At every node in every tree of a random forest, a limited number of parameters are selected at random and used to partition the data. Doing this over many trees allows these models to not be as heavily influenced by minor changes to the training datasets. Statistical conditions applied to the random forest for classifying chlorine exceedances are presented in **Table 3-7**.

Table 3-7 Random Forest Model Configuration

Random Forest	
Type	Classification
Prediction	Chlorine Exceedance
Number of decision trees	500
Number of randomly selected parameters per node	14
Bootstrap sampling method	With replacement
Minimum observations in required terminal nodes	7
Cross-validation type	Monte-Carlo
Cross-validation computes	25

The random forest was the most accurate of the models with a measure of 67% ±7%. **Figure 3-12** shows the top 20 variables deemed most important to exceedance events by each statistical model. Similar to the decision tree and logistic model, disinfection dose and plant BOD loading were strong drivers. Other notable factors include effluent TSS, Visy Paper loading, and RAS loading rates. Surprisingly, precipitation was not identified as a significant factor.

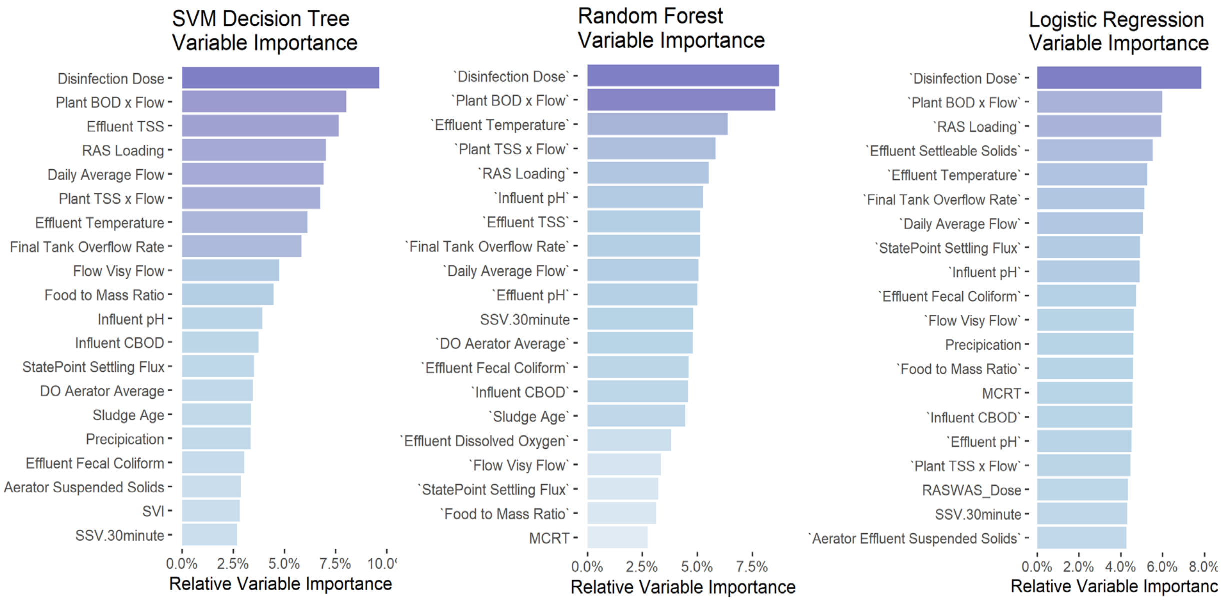


Figure 3-12 Factors Most Often Occurring When Effluent TRC Exceeded 0.52 mg/L

3.9.1.4 Regression

Due to the class imbalances, standard regression analyses were not used as there are insufficient observations of high chlorine concentrations in the effluent. Even so, spearman regression coefficients were computed throughout the entire dataset as a measure of monotonicity and most parameters returned R^2 values less than 0.1. Values that returned higher than 0.1 were either directly related to chlorine such hypo pump flow, or had a p-value >0.05 indicating the regression coefficient is statistically insignificant likely due to lack of coincident samples between TRC concentration and the predictor variable.

Figure 3-13 displays box plots showing the predicted variable (effluent TRC concentration) as a function of some of the variables deemed significant by the variable importance evaluations. Box and whisker plots are distribution plots where the box represents the interquartile range (25th to 75th percentile) of the observations, the whiskers represent 1.5x the interquartile range, and points outside of the whisker range are considered outliers.

Figure 3-14 shows TRC concentrations as a function of binned chlorine dose. The data were binned (grouped) to better identify trends associated with chlorine residual concentrations that are not easily recognizable in standard regression and as expected, the spread of residual concentrations increases as chlorine doses increase. Similarly, when observing BOD loading rate to the facility, the likelihood of exceedance events increase as greater concentrations of chlorine residual in the effluent are observed in BOD loading rate bins of higher concentrations. Because Visy Paper comprises a significant portion of the facility's BOD load, **Figure 3-15** is showing that as the Visy Paper flow increases, the median effluent TRC as well as the IQR of chlorine concentrations also increase. This may imply a potential contributing factor to activated sludge instability and resultant higher TRC concentrations.

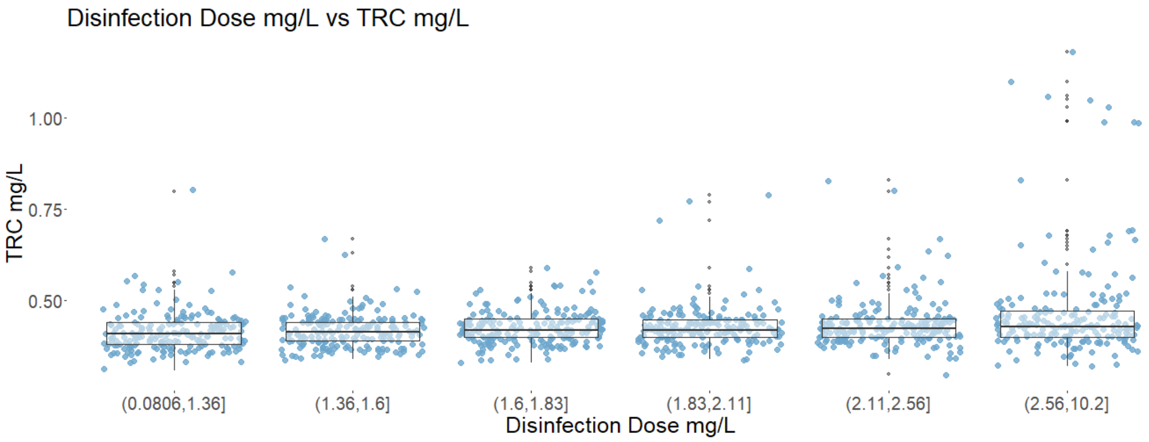


Figure 3-13 Effluent TRC concentrations by Binned Disinfection Dose (Bin intervals defined such that they contain an equivalent number of TRC observations)

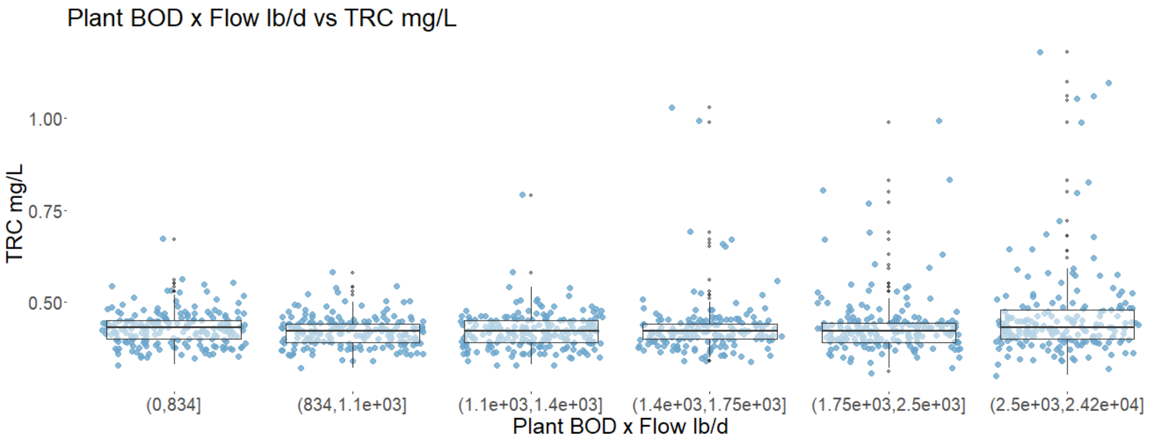


Figure 3-14 Effluent TRC concentrations by Binned influent BOD Loading Rate (Bin intervals defined such that they contain an equivalent number of TRC observations)

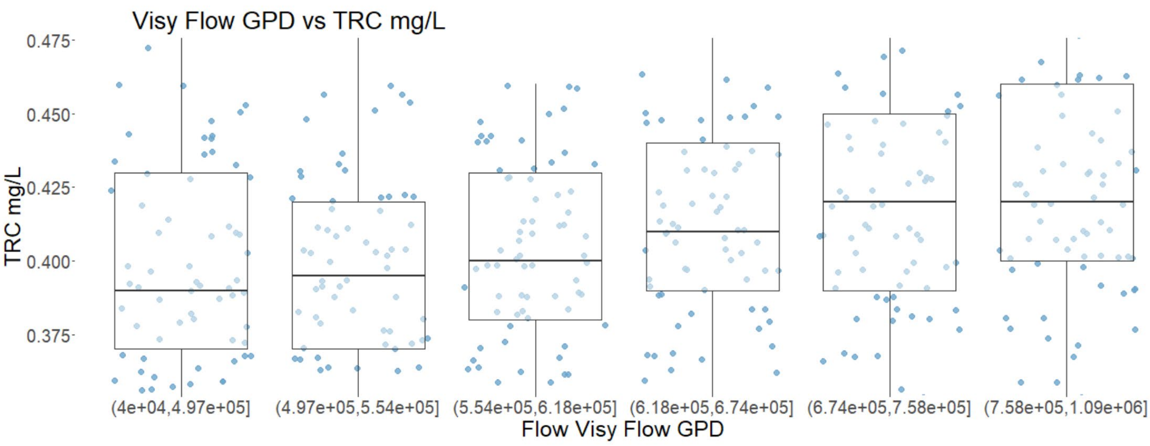


Figure 3-15 Effluent TRC concentrations by Binned Visy Paper Flow Rate (Bin intervals defined such that they contain an equivalent number of TRC observations) [*]Plot is zoomed in and does not show all TRC observations

Figure 3-16 shows chlorine concentrations as a function of binned effluent fecal coliform concentrations. This plot provides insight into when bacterial concentrations start to increase the probability of an exceedance event which becomes increasingly apparent when 7-day geomeans approach 200 cfu/100mL (notably, the permit limit is a 30-day geomean of 200 cfu/100mL) indicating operators likely prioritize meeting bacterial permit limits above achieving the proposed TRC limit.

Effluent TSS bins are shown in **Figure 3-17** to illustrate the increasing probability of higher chlorine concentrations associated with high effluent TSS. TSS is another factor associated with the activated sludge process and can be affected by BOD and process performance. Although higher TSS may exert more chlorine demand and result in less residual, several log sheets indicated that operators tend to increase chlorine dose when solids are notably higher in the influent to the chlorine contact tanks to ensure an adequate bacterial kill.

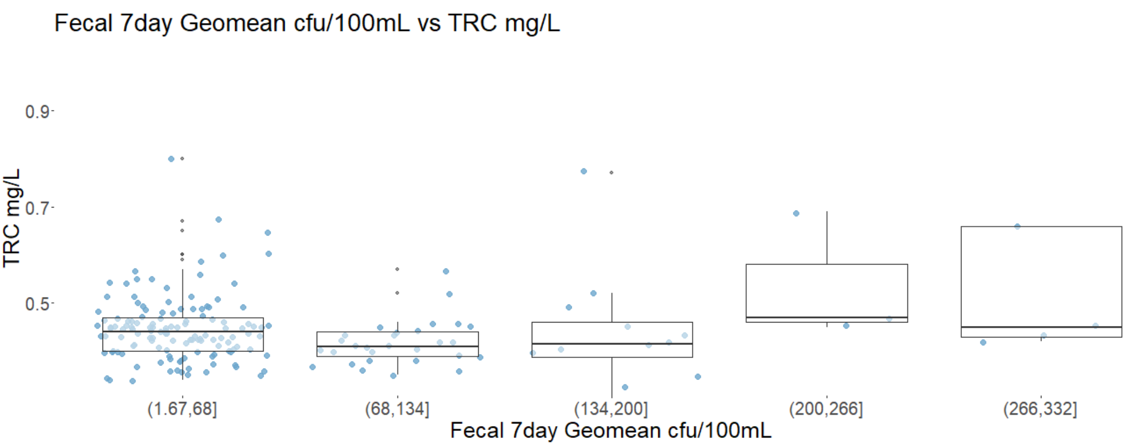


Figure 3-16 TRC concentrations by Binned Fecal Coliform 7-day Geomean (Bin intervals defined such they are the same length independent of number of observations) [*]Plot is zoomed in and does not show all TRC observations

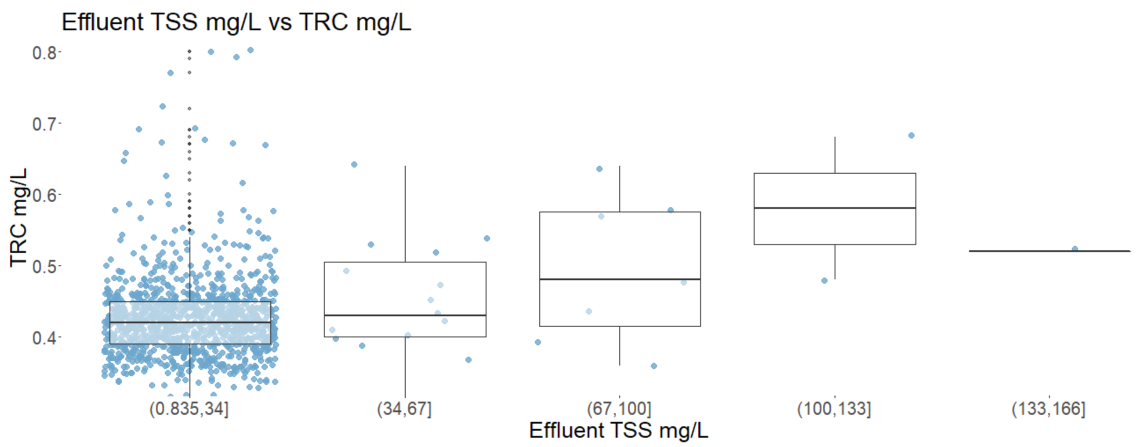


Figure 3-17 TRC concentrations by Binned Effluent Suspended Solids (Bin intervals defined such they are the same length independent of number of observations) [*]Plot is zoomed in and does not show all TRC observations

3.9.1.5 Results of Statistical Evaluations

Results of the statistical evaluation provided insight into factors that were weighted heavily when predicting if the facility will have experience a chlorine exceedance event. The entropy-reduction based approaches (Decision Tree and Random Forest) as well as the binary regression approach (Logistic Regression) all shared the similar feature importance metrics where disinfection dose, BOD loading, RAS loading, effluent TSS, and Visy paper flows were indicative of TRC exceedance risks. Metrics pertaining to secondary treatment such as solids settleability, F/M, and sludge age were also common. Because feature importance is spread out without heavily weighted major predictors, the implication is that variability amongst the features listed have relatively comparable probabilistic impacts on residual chlorine concentrations.

Section 4
Conclusions and Recommendations

4.1 Conclusions

It is clear from recent plant operating data, that the Port Richmond WRRF can routinely achieve its required fecal coliform inactivation while also operating with a low effluent TRC, well below the anticipated new effluent target of 0.52 mg/L. Data from the last TRC and Fecal Performance Update showed that from November 2019 through October 2020, the monthly average effluent TRC ranged from 0.23 to 0.32 mg/L. However, the daily maximum TRC for this same period ranged from 0.30 to 0.96 mg/L, exceeding the target of 0.52 mg/L for 2 out of 12 months. The issue becomes one of consistency, and whether the plant can consistently operate with a daily maximum effluent TRC below the 0.52 mg/L target while also meeting fecal inactivation. This appears to be further challenging if NYSDEC were to adopt the enterococcus STV of 30 cfu/100 mL as an effluent limit. During the summer 2020 sampling event, the mean effluent TRC was 0.43 mg/L, while the geometric mean for enterococcus and fecal coliform were 36 and 114 cfu/100 mL, showing that the results were well within the 30-day fecal limit, but exceeding the enterococcus STV.

No single causative factor could be identified as resulting in the exceedances of the TRC target. Rather there appear to be multiple, complex factors that are contributing to the variability in the control of the effluent TRC. The major factors affecting disinfection performance and the resulting chlorine dose and residual include:

- Effluent quality variability (chemical composition and bacterial counts),
- Impact of Pratt/Visy Paper discharge on the plant secondary treatment performance,
- Variable chlorine demand and the use of manual chlorine dose adjustment strategy rather than automated control with residual feedback,
- Impact of bulking sludge and filamentous growth events on the process operations including effluent quality and chlorine dose,

A somewhat brute-force statistical analysis of this historical data since the completion of the chlorination upgrade in 2016 identified common factors most associated with TRC exceedances:

- Disinfection dose
- Plant BOD loading
- Effluent TSS
- RAS loading
- Daily flow
- Plant TSS loading

- Effluent temperature

Effluent variability is viewed as a major factor impacting the overall disinfection performance and the ability to tightly control the TRC residual below the 0.52 mg/L target while also maintaining bacterial inactivation. It is notable that during the summer 2020 sampling event, the concentration of both fecal coliform and enterococcus in the CCT influent varied by over 2-logs. Because the effluent bacteria concentration is a function of the influent concentration and the CCT log reduction for a given chlorine dose and contact time, a 2-log increase in the influent concentration will result in a proportional increase in the effluent concentration. Most often, this will appear as noise in the effluent bacteria monitoring, forcing the operator to increase the chlorine dose in order to decrease the daily bacteria results, or when there is a trend that might exceed 7-day or 30-day reporting limits. Effluent variability can also result in significant variability in chlorine demand, which can be difficult to compensate for without using automatic control and residual feedback. With the current strategy of manual dose adjustment based on hourly grab sample analysis, the dose adjustment will always be lagging the process.

The presence of bulking sludge and filamentous growth is a recurring problem at the Port Richmond WRRF. This appears to be affecting the disinfection system performance both based on operation and on disinfection log-reduction. The plant operators over the summer sampling event adjusted the disinfection dose when they were chlorinating RAS, making it more difficult to consistently meet a low residual limit. Additionally, it is possible that at times during these events, the solids composition of the effluent TSS is different resulting in a larger particle size distribution. Larger particles in the effluent can reduce disinfection effectiveness by partially shielding bacteria within the solids particle and requiring a higher chlorine dosage to achieve the same log reduction. On average, TSS removal is quite good with mean effluent TSS of 8.3 mg/L since 2016. However, poor settling sludge has often been observed, including recently when visible paper particles were reported in SVI column tests. It is also notable that PSD analysis performed during the summer 2020 sampling event showed a significant shift to larger particles as compared to PSD analysis performed in 2005 as part of the initial TRC Program.

The discharge from Visy Paper is likely contributing to and exacerbating the bulking sludge and filamentous growth occurrences at the plant. This is also compounded by the condition of the aeration system (i.e., dead spots, broken air headers/diffusers, lack of oxygen/DO control) and control of flow splitting. The BOD loading from Pratt/Visy Paper represents upwards of 50 percent or more of the total plant BOD loading. It is unclear whether this discharge is relatively constant or more of a batch discharge and whether the BOD is mostly in the soluble form or particulate. If it is mostly soluble as would be expected from this type of discharge and on a shift or batch basis, this further impacts the secondary process by promoting the conditions for bulking sludge and filamentous growth.

Precipitation and settling flux capacity did not correlate well with TRC exceedances. Certain large precipitation events, primarily those resulting in some solids washout, did result in process upsets which led to TRC exceedances. But most precipitation events did not seem to impact TRC compliance. Regarding settling flux, the final settling tanks are typically operated well below their theoretical settling flux. Over the period evaluated, the state point only approached the theoretical settling flux on three days, two of which corresponded with TRC exceedances. Many other times the state point was elevated without observed TRC exceedances, and conversely many other times the state point was low while there were TRC exceedances, which indicated that the two were poorly correlated.

4.2 Recommendations

The Port Richmond WRRF is performing quite well in meeting a low TRC target while also achieving bacteria effluent limits, given some of the challenges at the plant. The following recommendations are made to improve the overall disinfection performance and provide a more consistent effluent TRC. Given how close the plant has maintained TRC and disinfection performance over the last year, it seems likely that with some or all of these recommendations that they could more reliably meet a TRC target of 0.52 mg/L.

- Repair/upgrade the secondary treatment process, including:
  - Aeration system improvements
  - Flow distribution improvements including replacement of stuck gates and valves
- Address the Visy/Pratt Paper discharge to reduce BOD loading on the WRRF
- Improvements to the chlorination control system, including:
  - Address the effluent flume flow monitoring and surcharge issue so that it can be used for dose pacing,
  - Perform regular maintenance and calibration of the Prominent TRC probes,
  - Operate the chlorination system in automatic mode with dose pacing and residual feedback.

Appendix A

PLC Data

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Appendix B

Port Richmond Sampling Program

Memorandum

To: *Jayne Beckmann*

From: *Joshua Registe, Mary Anne Taylor, P.E.*

Date: *September 23, 2020*

Subject: *Port Richmond Sampling Program Results*

Purpose and Scope

The purpose of the wastewater sampling at Port Richmond Wastewater Resource Recovery Facility (WRRF) is to characterize the variability of pathogen indicators in wastewater entering the facility, after primary treatment, after secondary treatment and after disinfection to assess the impact of upstream processes upon disinfection effectiveness. Samples of chlorine contact tank (CCT) effluent, final tank effluent, primary effluent and plant influent were collected by Macan Deve Engineers (MDE) and transported to New York Environmental Consultants and Laboratories (NYE) where testing was conducted to assess disinfection. Field parameters and analysis performed included temperature, pH and total residual chlorine.

The objectives of this technical memorandum are to present the results of the sampling program and highlight specific water quality parameters that are not typically measured at the facility that are pertinent to disinfection and may affect performance.

Testing

Samples of CCT effluent, final tank effluent, primary effluent and plant influent were collected daily (Monday through Friday) for a 12-day sampling period starting 6/29/2020 and ending 7/17/2020. Sampling was skipped on 7/2/2020 – 7/6/2020 for the observation of July 4th, Independence Day. Samples were collected from the sampling locations shown in **Figure 1,** moving sequentially from the effluent end of the CCT upstream to the plant influent; e.g., from the most highly treated sample location to untreated wastewater, and were transported by members of the field sampling team to NYE's laboratory. See *PW-TRC-PDR Port Richmond WRRF Field Sampling Plan* for specific details on the sampling plan and locations.

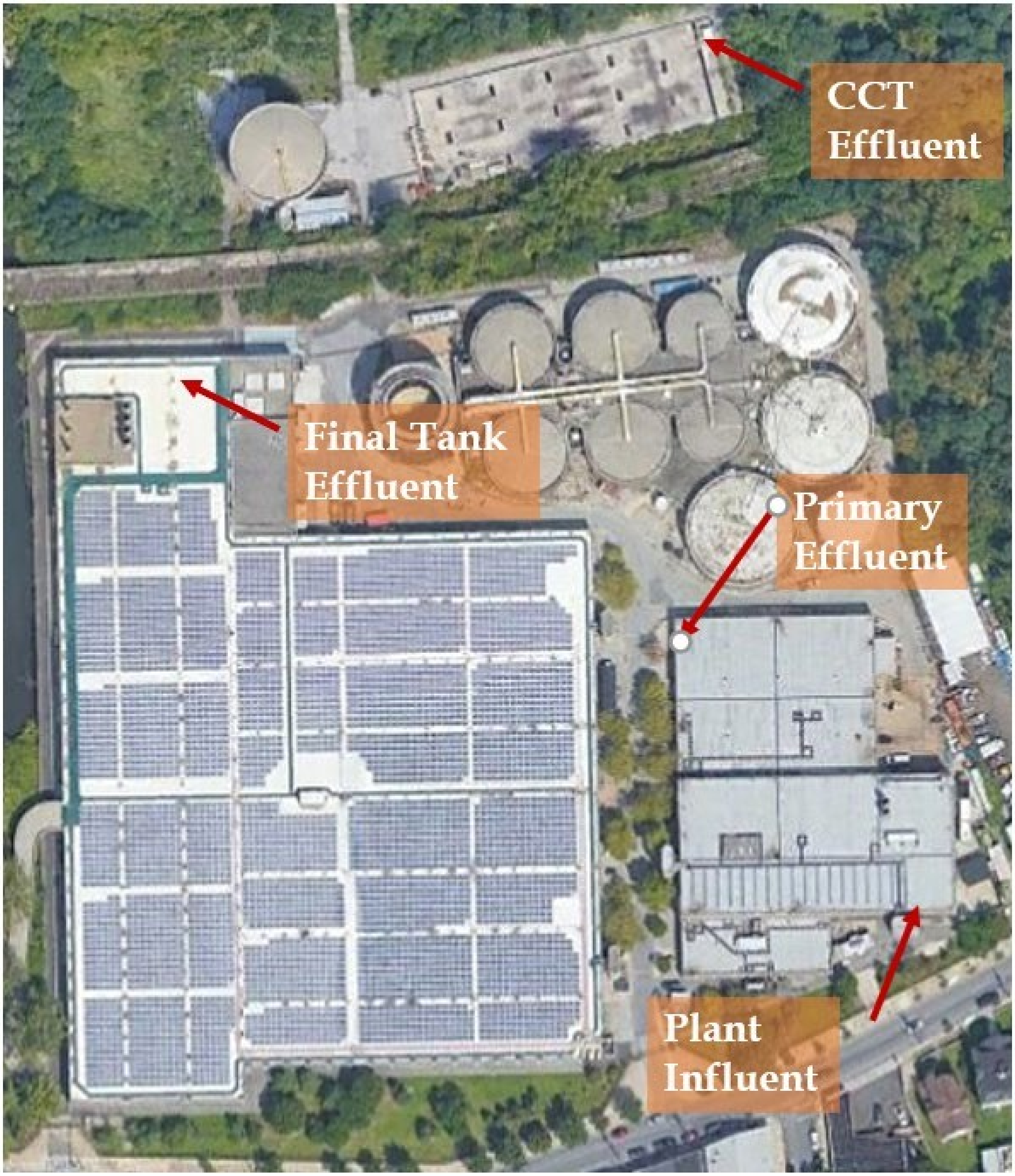


Figure 1 - Port Richmond Sampling Locations

The 10-day sampling program was extended to 12 days to collect additional samples at each location and the full count of measurements is provided in **Table 1**. Results from one carbonaceous biological oxygen (cBOD) and one total suspended solids (TSS) sample were not analyzed as they exceeded the holding time during shipment. The fecal coliform samples collected on five days could not be used due to an apparent equipment malfunction at the NYE laboratory. Duplicate measurements of fecal coliform and enterococcus were collected at the final tank effluent for QA/QC and to capture supplementary data for the influent bacterial loading into the chlorine contact tanks (CCT). DEP provided additional data at the end of the sampling program for each of the days sampled including sludge volume index (SVI), sludge cylinder reading, and mixed liquor suspended solids (MLSS) concentrations.

For detailed information on the sampling results:

- See **Appendix A** for **Sampling Results**
- See **Appendix B** for **DEP Notes and Sampling Results**
- See **Appendix C** for **Chlorine Demand Standard Operating Procedure**
- See **Appendix D** for **Particle Size Distribution Report**

Table 1 – Number of Samples Collected from Each Sample Location

Parameter	Parameter Abbreviation	Plant Influent	Primary Effluent	Final Tank Effluent	CCT Effluent	Aeration Tank Effluent
Fecal Coliform	FC	12	12	24	12	-
Enterococcus	EC	12	12	24	12	-
TSS	TSS	12	12	12	12	-
cBOD	cBOD	12	12	12	12	-
Lab TRC[1]	LTRC	-	-	2	-	-
Particle Size Distribution XAD	XAD	-	-	-	-	2
pH	pH	12	12	12	12	-
Temperature	T	12	12	12	12	-
Field TRC	FTRC	12	12	12	12	-
SVI	SVI	-	-	-	-	12
MLSS	MLSS	-	-	-	-	9
Cylinder Reading Average	CRA	-	-	-	-	12
Flow	Flow	12	-	-	-	-

[1] – Lab TRC represents 5-gallon sample taken to perform chlorine demand test

Sampling Program Results

This section of the memorandum presents the results of the sampling program as follows:

- Bacterial results
- TRC, cBOD and TSS results
- Chlorine demand testing
- Particle size distribution
- Other (MLSS, plant flow, SVI)

DEP has provided notes for each of the sampling days which include information pertinent to plant performance and disinfection. Process control information on chlorine target residual was provided and the target residual was increased three times throughout the 12-days of sampling program. During the initial days of the sampling program, DEP maintained a residual target of 0.25 mg/L which is relatively low in comparison to the residual target of 0.4 mg/L identified in Port Richmond's historical daily monitoring reports (DMR). The residual target was increased to 0.35 mg/L on July 7th (the 4th sampling day) and then to 1 mg/L on July 10th (the 7th sampling day). This residual target increase is likely due to the relatively high effluent bacteria concentrations observed the days prior. The residual target was reduced to 0.45 mg/L on July 13th (the 8th sampling day) and stayed as such for the remainder of the program.

Another chlorine application point at Port Richmond is within the recycled activated sludge (RAS). RAS is chlorinated to mitigate bulking sludge and filamentous organism growth that may be caused by poor aeration control. DEP has provided information on RAS chlorination and during the first four sampling days, the chlorine dose was relatively high at 8.8 mg/L. This may explain why the TRC target was set lower than usual (0.25 mg/L). RAS chlorination was reduced to 6.3 mg/L on the 4th day of sampling (and the chlorine residual target was increased to 0.35 mg/L) and then dropped to 0 mg/L from the 8th day onward. Additional details on foaming, precipitation, and other notes can be found in **Table 2.**

Table 2 – DEP Sampling Program Notes

Day	Date	TRC Target (mg/L)	RAS Chlor Dose (mg/L)	Foaming Condition	Rain Day (Yes/No)	Contractor work*	MLSS (mg/L)	Notes
1	6/29/2020	0.25	8.8	Heavy	No	--	1160	Experienced foaming as a result of M. Parvicella filaments
2	6/30/2020	0.25	8.8	Heavy	No	Yes	1070	Contractor work on June 30th and July 14th required the primary sludge pumping to be off during the sampling time period which may have affected the quality of primary effluent.
3	7/1/2020	0.25	8.8	Heavy	Yes	--	980	
(NO SAMPLING)	7/2/2020	0.25	8.8	Heavy	Yes	--	800	
4	7/7/2020	0.35	6.3	Medium	No	--	1020	
5	7/8/2020	0.35	6.3	Medium	No	--	780	
6	7/9/2020	0.35	6.3	Light	No	--	670	
7	7/10/2020	0.35 to 1.0	6.3	Light	Yes	--	560	
8	7/13/2020	0.45	Off	None	No	--	770	
9	7/14/2020	0.45	Off	None	No	Yes	765	Contractor work on June 30th and July 14th required the primary sludge pumping to be off during the sampling time period which may have affected the quality of primary effluent.
10	7/15/2020	0.45	Off	None	No	--	760	
11	7/16/2020	0.45	Off	None	No	--	770	
12	7/17/2020	0.45	Off	None	No	--	780	

Bacterial Results

Treated effluent from the Port Richmond WRRF discharges to the Kill Van Kull, which is identified as a Class SD water by the Department of Environmental Conservation (DEC). The best usage of Class SD waters is fishing. Class SD waters must be suitable for fish, shellfish and wildlife survival and the water quality shall be suitable for primary and secondary contact recreation, although other factors may limit these uses. New York State also identifies that Class SD waters may not meet the requirements for fish propagation due to natural or man-made conditions.

The existing DEC State Pollutant Discharge Elimination System (SPDES) discharge permits for all fourteen of the City's WRRFs require year-round disinfection and include limits for fecal coliform. Port Richmond WWTP SPDES permit NY0026107 includes the following effluent limits for fecal coliform:

30-day geometric mean fecal coliform:	200/100 mL
7-day geometric mean fecal coliform:	400/100 mL
6-hour geometric mean fecal coliform	800/100 mL
Instantaneous maximum fecal coliform:	2400/100 mL

In November 2012, EPA published 2012 recreational water quality criteria (RWQC) recommendations. The 2012 RWQC includes both a geometric mean and a statistical threshold value (STV); it also defines a magnitude, duration and frequency of excursion for both the geometric mean and the STV specifically for enterococcus.

The anticipated future permit requirement for enterococcus from the 2012 RWC is as follows:

Recommendation based on estimated illness rate of 36/1000:

30-day geometric mean fecal coliform:	35/100 mL
Statistical threshold value:	130 /100mL

Recommendation based on estimated illness rate of 32/1000:

30-day geometric mean fecal coliform:	30/100 mL
Statistical threshold value:	110/100mL

Results for fecal coliform and enterococcus at each sampling location are presented as a time series in **Figure 2** (Two values are shown for final tank effluent each day, as duplicate samples were collected and analyzed.). **Figure 3** provides a box plot distribution of these bacterial concentrations at each location to show the variability of bacterial concentrations observed.

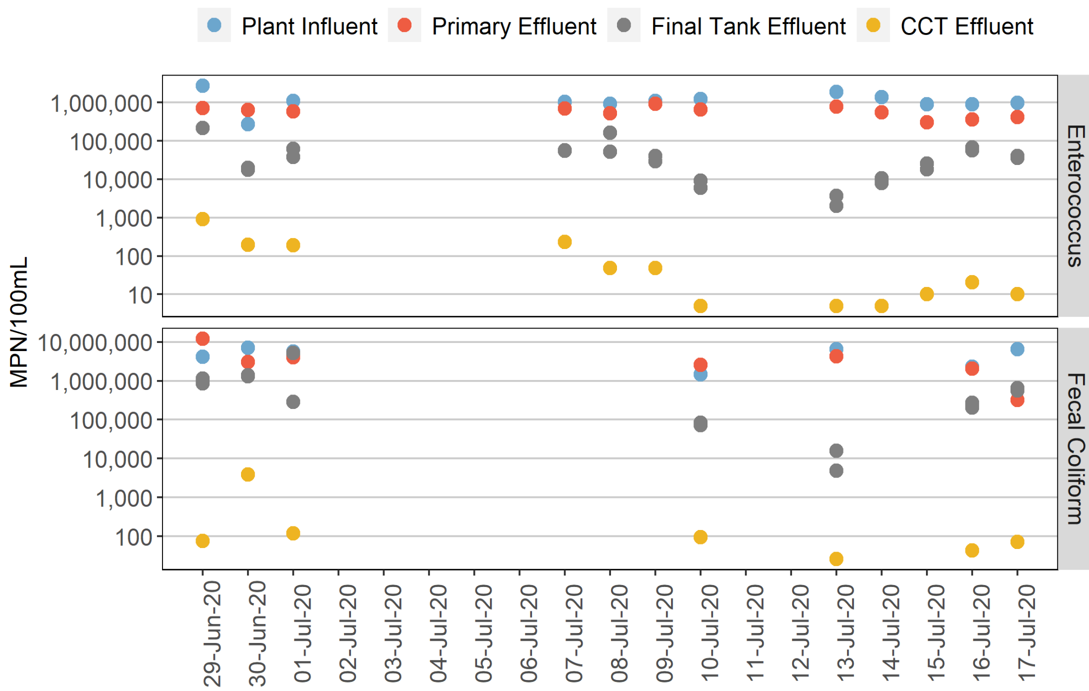


Figure 2 – Port Richmond Bacterial Concentrations Sampling Time Series

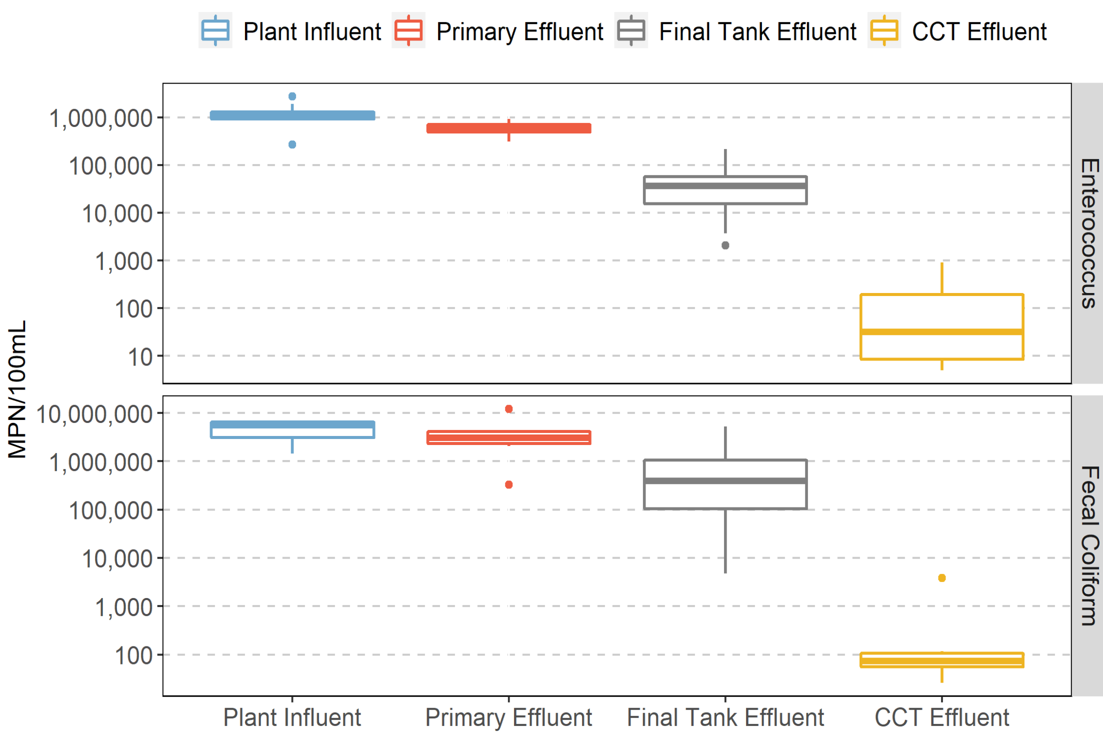


Figure 3 – Port Richmond Bacterial Concentration Distributions by Location

Throughout this 12-day period, the influent bacterial concentrations to the facility were consistent, with one exception for enterococcus with a concentration of $2.68 * 10^5$ MPN/100mL on the first day of sampling. No significant reduction in bacterial concentrations resulted from primary treatment (red and blue dots).

The reduction in bacterial concentrations across secondary treatment varied during this sampling program, such that bacterial loading to the CCTs varied by more than two orders of magnitude, with influent enterococcus between 10^3 – 10^5 MPN/100mL and influent fecal coliform between 10^4 – 10^6, suggesting that secondary treatment can have a significant impact on disinfection. This variance in influent quality to the CCTs over this short period of time can lead to a variability in chlorine demand and difficulty maintaining both pathogen kill and a target residual. **Table 3** presents summary statistics of CCT influent and effluent bacterial concentrations. For reference, historical bacterial concentrations are also presented from Port Richmond's DMRs.

Table 3 – Summary Statistics of Port Richmond Bacterial Concentrations

Parameter	Final Tank Effluent Enterococcus (MPN/100mL)	Final Tank Effluent Coliform (MPN/100mL)	CCT Effluent Enterococcus (MPN/100mL)	CCT Effluent Fecal Coliform (MPN/100mL)
	[Historical 3/1/2016 – 4/30/2020] (Sampling Program 6/29/2020 – 7/17/2020)			
Sample Count	NA/12	NA/7	38/12	1,159/7
Min	NA/2,875	NA/10,300	1/5	1/26
2nd Percentile	NA/3,926	NA/18,406	1/5	2/28
Geomean	NA/29,582	NA/330,504	4/36	45/114
98th Percentile	NA/139,384	NA/2,588,280	473/761	1,297/3,402
Max	217,600	2,758,500	1020/910	4,000/3,850

[1] –The first value represents historical data and the second value represents 2020 sampling program statistics

TRC, cBOD and TSS Results

Results for TRC, cBOD and TSS are presented **Figure 4** as a time series plot throughout the sampling program duration. **Figure 5** shows the distribution of this data at each sampling location. Chlorine residual was measured at each location using the Hach CL17. However high turbidity and color can lead to unacceptable accuracy in the results from the Hach AccuVac DPD method. This is the suspected explanation for the Hach CL17 instrument measuring chlorine residual in the plant influent. This high strength wastewater is expected to have no chlorine residual. Chlorine residual readings are more likely to occur downstream of the plant influent where chlorinated RAS may be recycled

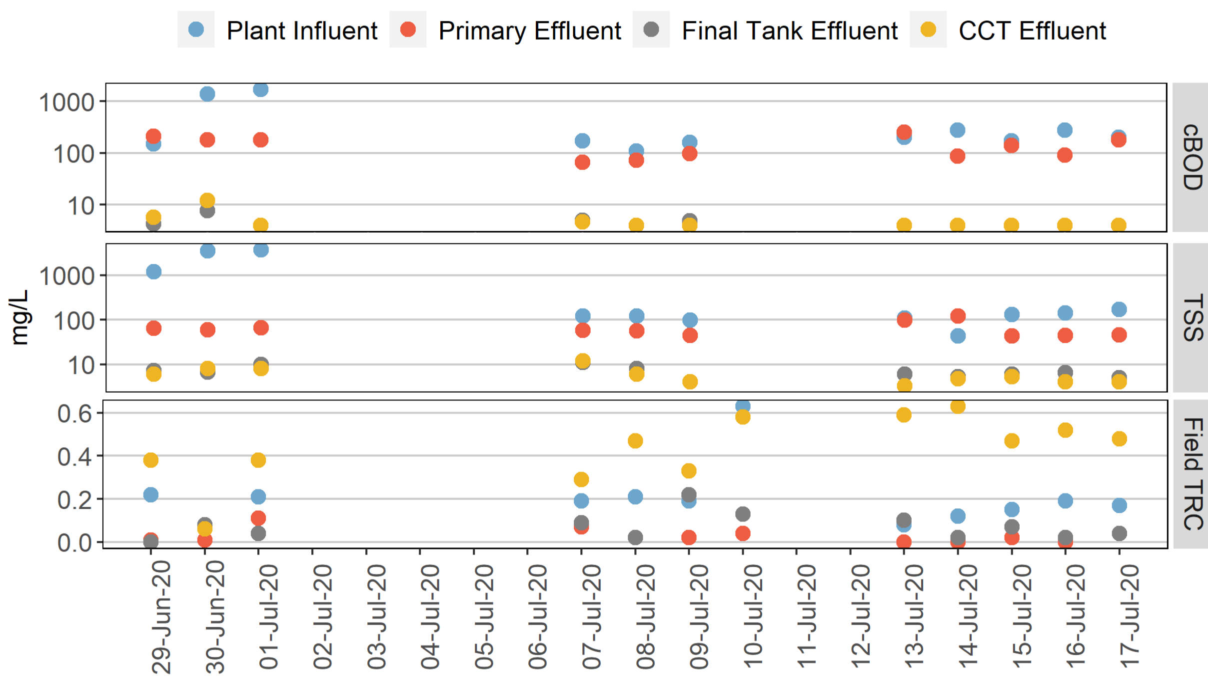


Figure 5 - Port Richmond cBOD, TSS, and TRC Concentrations Sampling Time Series

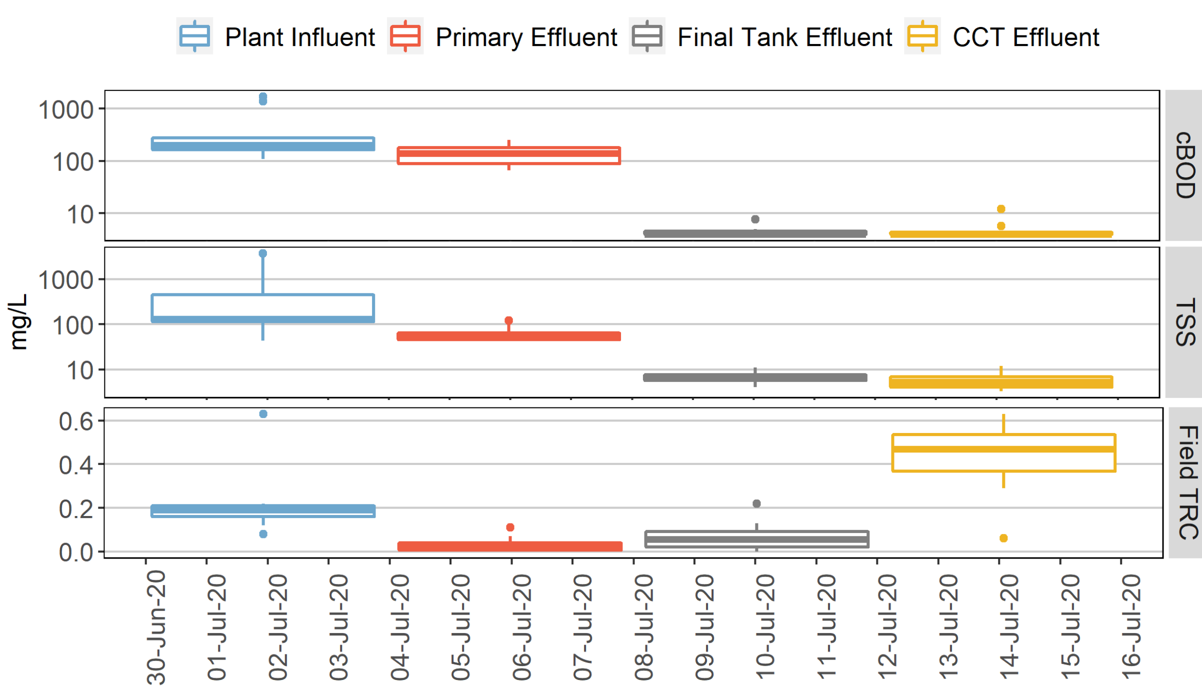


Figure 4 - Port Richmond cBOD, TSS, and TRC Concentrations by Location

During the first three days of sampling, both influent cBOD and TSS exceeded 1,000 mg/L. Two extremely high influent TSS samples were observed on the second and third day of sampling with influent measurements of 3,500 mg/L and 4,000 mg/L respectively. As shown in **Table 4**, historically, Port Richmond has never reported a daily average value this high, however the DMR data is based on daily average composite samples while the sampling program is based on a single grab sample. (Port Richmond AT sheets do report an influent TSS concentration of 1,543 mg/L on July 20th, after this characterization program had been completed.) The cBOD values for that day were high as well possibly due to the particulate fraction from a high TSS sample.

The June and July Pratt Paper **Daily Effluent Analysis** provided TSS and cBOD concentrations and loads for six days during June and four days during July, none of which coincided with the June 29th through July 1st sampling period when the high TSS and cBOD concentrations were measured in the influent grab samples. The reported average cBOD concentrations for the months of June and July exceeded 6,000 mg/L. The reported average TSS concentrations were 60 and 66 mg/L for June and July respectively, both considerably lower than the observed influent TSS concentrations at the plant.

Pratt Paper's reported average daily cBOD load for July was 30,498 lbs/day, while Port Richmond reported an average daily cBOD load of 71,681 lbs/day. However, on July 15th, both Port Richmond and Pratt Paper reported influent CBOD loads; on that day the reported Pratt Paper cBOD load was 27,759 lbs/day, while the reported Port Richmond load was 13,894 lbs/day (see Process sheet, cBOD influent loading). This discrepancy is presumably attributed to different sampling times, but indicates that Pratt Paper likely comprised most of the cBOD loading to the plant on that day.

The primary treatment system was effective in reducing both the CBOD and TSS loads, but it is possible that the type of solids and this variation in cBOD load could negatively impact biological treatment systems and propagate downstream causing complications within disinfection processes. The distribution of effluent TRCs throughout the sampling program was consistent with observations recorded historically in the DMRs – both with a mean residual of 0.43 mg/L.

Table 4 – Summary Statistics of Port Richmond cBOD, TSS, and TRC Concentrations

Parameter	Influent CBOD (mg/L)	Influent TSS (mg/L)	Effluent CBOD (mg/L)	Effluent TSS (mg/L)	Effluent TRC (mg/L)
	[Historical 3/1/2016 – 4/30/2020] (Sampling Program 6/29/2020 – 7/17/2020)				
Sample Count	1,160/11	1,160/11	1,160/11	2,298/11	1,16012
Min	57.0/110	59/43	0.0/4.0	1.0/3.3	0.30/0.06
2nd Percentile	137/118	81/54	3.0/4.0	2.5/3.4	0.34/0.11
Mean	331/438	170/843	9.5/4.9	8.2/5.9	0.43/0.43
98th Percentile	610/1,640	388/3,660	34.8/10.7	35.1/11.2	0.65/0.62
Max	1,698,/1,700	2,000/3,700	132.0/12.0	166.0/12.0	1.18/0.63

[1] –The first value represents historical data and the second value represents 2020 sampling program statistics
[2] – Historical values are daily average composites while sampling program is based on one discrete sample per day

Chlorine Demand Testing

Chlorine demand is significantly impacted by the physical and chemical characteristics of wastewater. Suspended particulates can partially shield bacteria from chemical disinfectants by limiting diffusion of disinfectant through the solid particles. Chlorine can also react directly with the solid particles which increases chlorine demand. Other factors affecting chlorine demand include temperature, pH, bacterial concentrations, and disinfection dose. Variability in factors that affect this demand can lead to complications in fine-tuning chlorine residual concentrations and resulting overdosing or underdosing. Port Richmond has several factors that can lead to variability in chlorine demand including:

- Highly variable influent plant BOD loads affecting secondary treatment and causing inconsistent food to mass ratios, settling characteristics, and bulking in activated sludge
- Variable CCT influent bacteria loads ranging between 10^4 – 10^6 MPN/100mL fecal coliform as observed throughout the sampling program
- Difficulty maintaining consistent dissolved oxygen levels throughout the aeration system leading to filamentous bacterial growth

Two chlorine demand tests for this study were conducted on the 8th and 10th day of sampling. 5-gallons of final tank effluent were collected on each day and the demand tests were conducted at 20°±1°C. The study was conducted as follows (see **Appendix C** for the full chlorine demand procedure):

- Screening investigation – Dosing 5 chlorine doses between 0.5 and 3 mg/L based on historical dosing concentrations and residual measurement are recorded after 5 minutes of contact time.
- Residual interpolation – Interpolating TRC results from screening evaluation to determine the chlorine doses required to achieve target residual concentrations of 0.2, 0.4, 0.6, 0.8 and 1 mg/L. These target residual concentrations were selected based on historical residual concentrations from the facility's DMRs.
- True demand investigation – Conducting demand investigation using interpolated doses required to achieve desired chlorine residual concentrations. Residual is measured at 2 minutes of contact time to obtain initial demand and then at 30 minutes of contact time to emulate contact tank hydraulic residence times. This demand investigation is run twice to obtain duplicate results and ensure adequate QA/QC.

Results of the two chlorine demand tests are presented in **Table 5** and **Table 6**. Results indicate that the initial demand (2-minute contact time) consumes the majority of the chlorine. The resultant total residual chlorine after 30 minutes of contact time that was obtained was expected based on the target residual. However, the dose to achieve the same target residual varied greatly between the two days and demand investigation 2 required an average 39% higher dose, indicative of the variable CCT influent quality. **Figure 6** and **Figure 7** show the demand difference between the two investigations. Influent bacterial concentrations of fecal coliforms during the sample day of investigations 1 and 2 were on the order of 103 and 104 MPN/100mL respectively.

Particle Size Distribution

Particle size distribution (PSD) was conducted at Particle Technology Labs using Single Particle Optical Sensing (SPOS) technology. This analysis was conducted on 2 separate sampling days on aeration tank effluent. PSD provides information on solids size distributions which can give insight into bulking sludge or changes in solids sizes that may affect disinfection.

The distribution of solids sizes by % volume is presented in **Figure 8**. The results for the first particle size sampling event (July 13, day 8) shows a large portion of the particle size between 20 and 200 μm with the distribution skewed heavily towards the larger particles in that range. This trend is consistent on the second particle size sampling event (July 15, day 10) as shown in **Figure 9**.

These results were compared to a PSD evaluation conducted in 2005; the results of the summer sampling event conducted July 2005 is presented in **Figure 10**. The 2005 distribution shows particle sizes ranging between 2.5 μm and 37.5 μm pointing towards a considerable increase in solids size over the past fifteen years, potentially resulting in wastewater that can become increasingly difficult to disinfect as the bacteria become entrained in the particles. The full particle size distribution report can be found in **Appendix D**.

Other Process Data

Table 7 presents additional plant data and operational metrics that were provided by the DEP during this sampling period which include plant flow, SVI, and MLSS. Historical data from Port Richmond's DMRs is also presented in **Table 7** for comparison. The facility was running at slightly lower flows and a higher SVIs than typical. Average MLSS was running lower than typical for the facility which can affect secondary treatment performance and sludge quality.

Investigation 1 Screening	
Starting Temperature C	Starting pH
19	7.31
Chlorine Dose (mg/L)	**TRC - 5 min (mg/L)**
0.5	0.1
1	0.3
1.5	0.48
2	0.69
3	1.14

Table 5 - Demand Investigation 1 (mg/L)

7/13/2020	Target TRC	Chlorine Dose	TRC - 2 min	TRC - 30 min	Demand
Initial	0.2	0.75	0.2	0.19	0.56
	0.4	1.25	0.38	0.34	0.91
	0.6	1.75	0.6	0.54	1.21
	0.8	2.25	0.7	0.71	1.54
	1	2.75	0.94	0.92	1.83
Duplicate	0.2	0.75	0.2	0.12	0.63
	0.4	1.25	0.38	0.23	1.02
	0.6	1.75	0.6	0.52	1.23
	0.8	2.25	0.7	0.64	1.61
	1	2.75	0.94	0.83	1.92

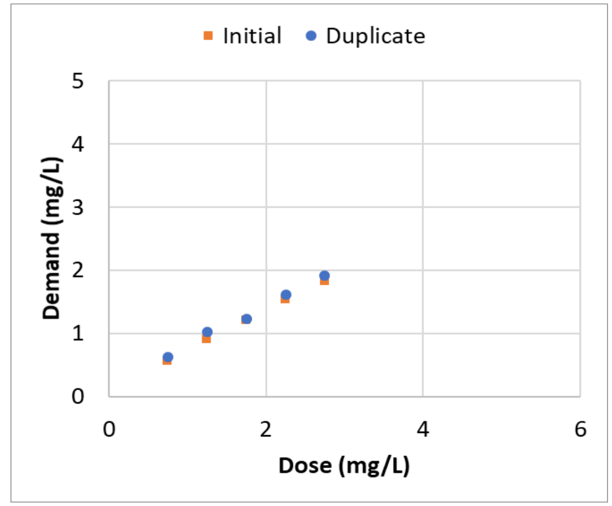


Figure 6 – Investigation 1 Dose vs Demand

Investigation 2 Screening	
Starting Temperature C	Starting pH
19	7.18
Chlorine Dose (mg/L)	**TRC - 5 min (mg/L)**
0.5	0.12
1	0.17
1.5	0.29
2	0.42
3	0.51

Table 6 - Demand Investigation 2 (mg/L)

7/15/2020	Target TRC	Chlorine Dose	TRC - 2 min	TRC - 30 min	Demand
Initial	0.2	1	0.24	0.18	0.82
	0.4	2	0.4	0.32	1.68
	0.6	3	0.6	0.49	2.51
	0.8	4	0.91	0.73	3.27
	1	5	3.73	1.06	3.94
Duplicate	0.2	1	0.24	0.17	0.83
	0.4	2	0.36	0.3	1.7
	0.6	3	0.56	0.42	2.58
	0.8	4	0.9	0.71	3.29
	1	5	3.92	0.92	4.08

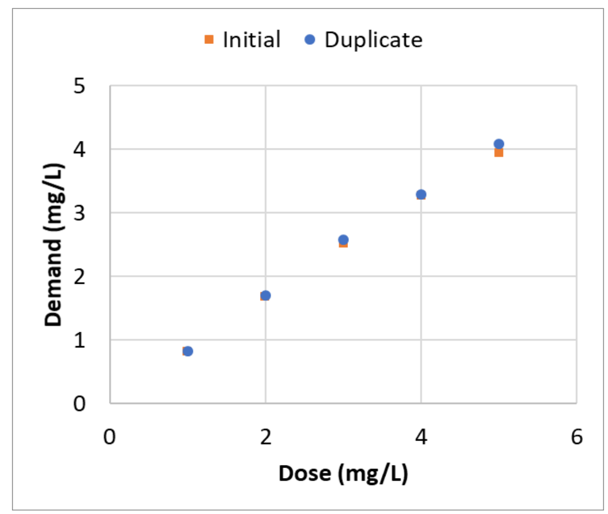


Figure 7 - Investigation 2 Dose vs Demand

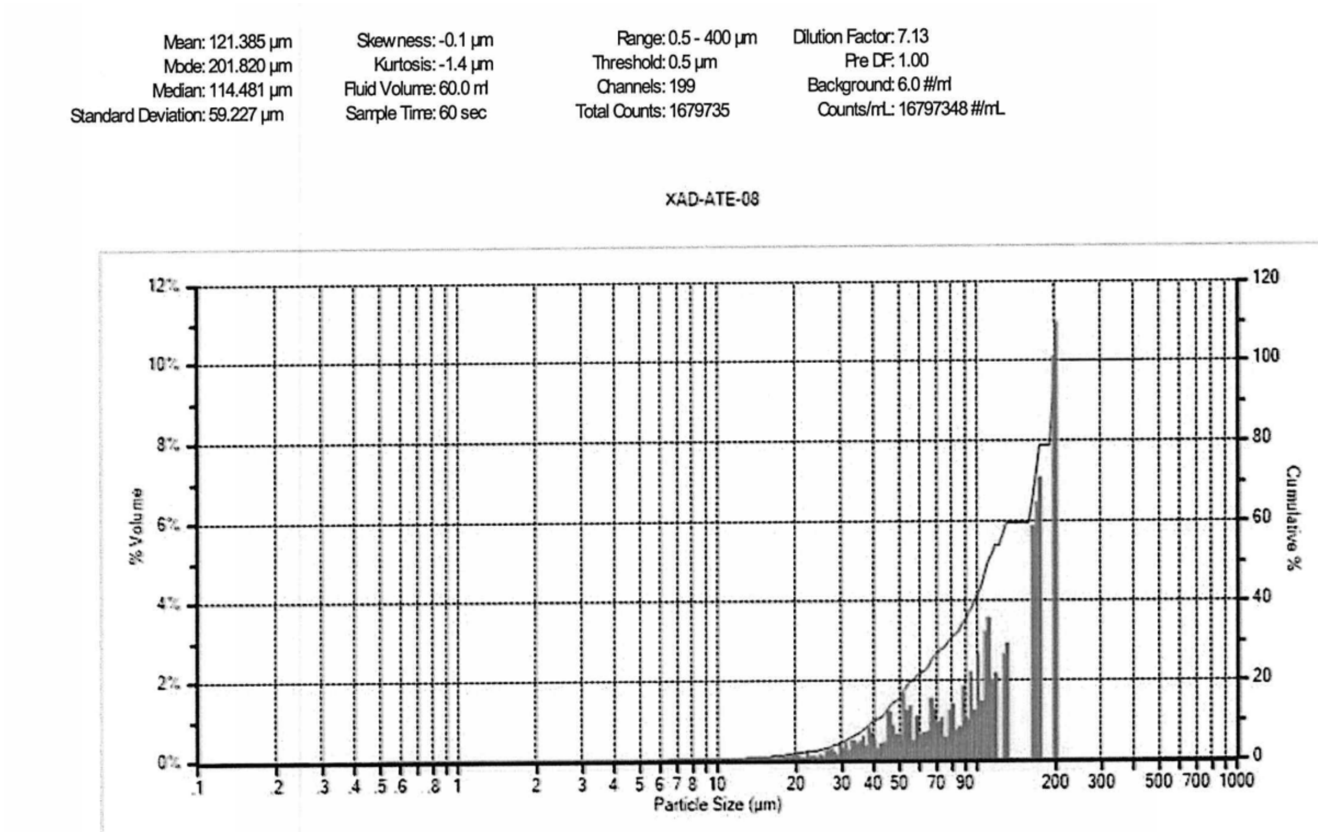


Figure 8 - Particle Size Distribution by Volume for Day 8 of 12

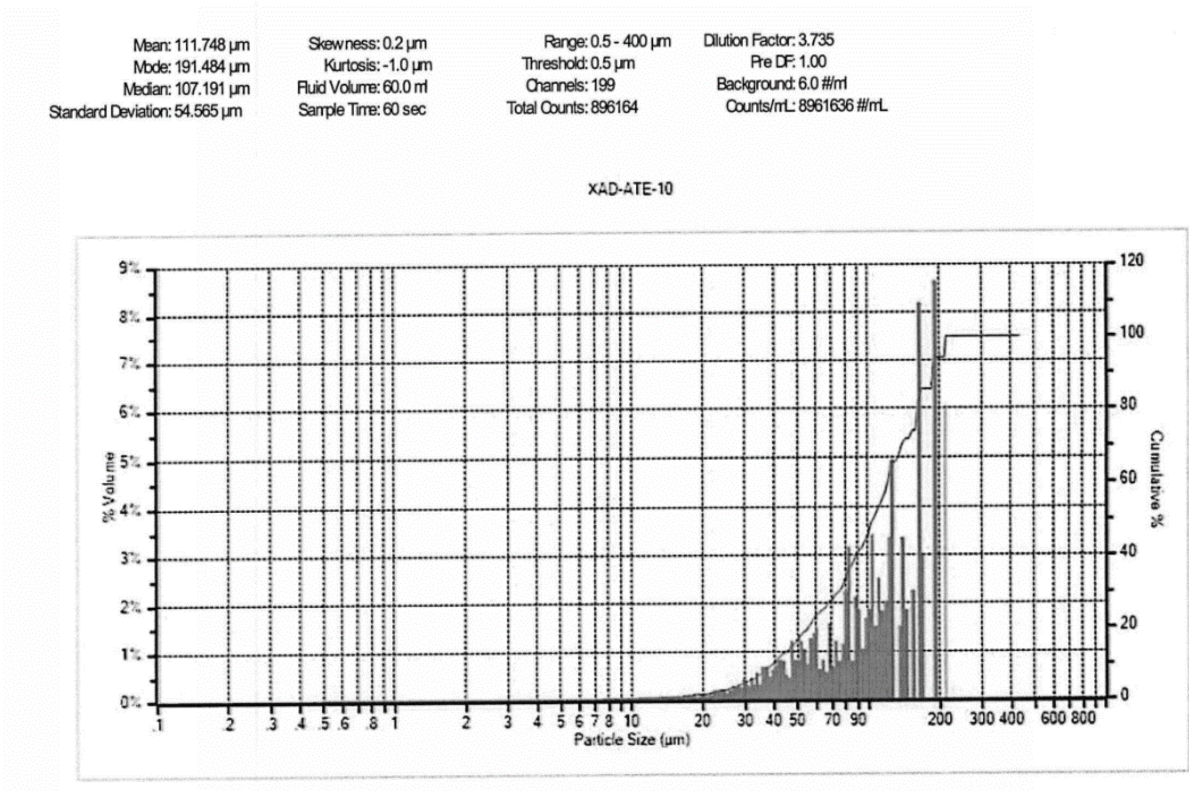


Figure 9 - Particle Size Distribution by Volume for Day 10 of 12

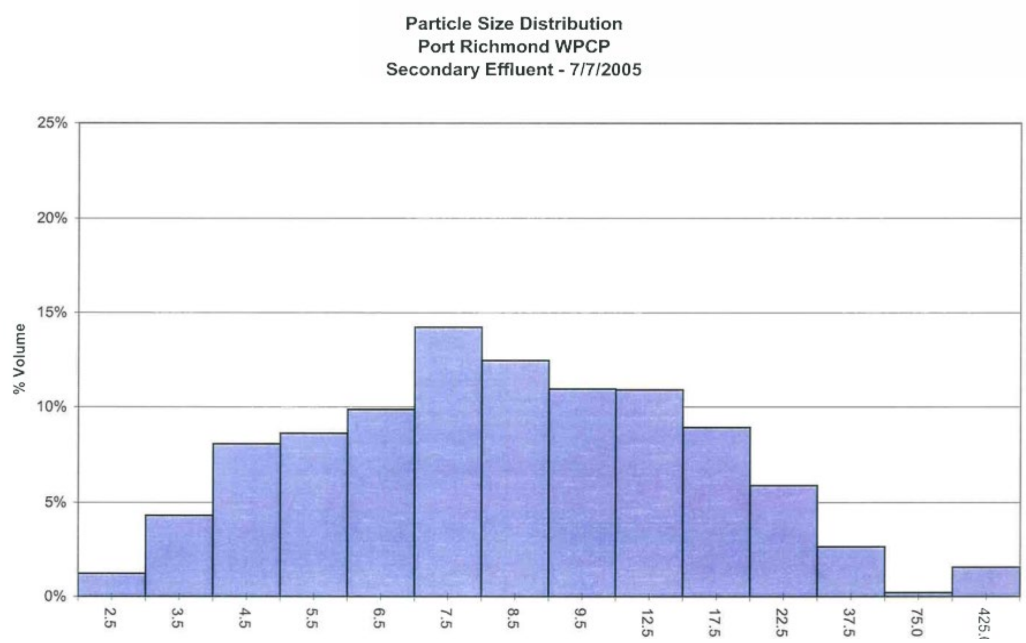


Figure 10 - July 2005 Particle Size Distribution Results

Table 7 – Additional DEP Operational Data

Parameter	SVI	Aeration Tank MLSS (lb/d)	Flow (MGD)
	[Historical 3/1/2016 – 4/30/2020] (Sampling Program 6/29/2020 – 7/17/2020)		
Sample Count	655/12	657/12	1160/12
Min	40/7	475/560	15.0/18.0
2nd Percentile	50/84	625/584	18.0/18.2
Mean	175/228	1,300/840	26.9/21.8
98th Percentile	460/415	2,604/1,140	57.0/29.9
Max	690/423	3,330/1,160	95.0/31.0

[1] –[1] –The first value represents historical data and the second value represents 2020 sampling program statistics

Conclusions

The wastewater characterization sampling conducted at the Port Richmond WRRF has resulted in the following observations and conclusions:

- Influent bacterial concentrations and primary treatment were relatively consistent.
- Reduction of pathogen indicators across the secondary process is not consistent, resulting in CCT influent concentrations that vary over two orders of magnitude.
- CBOD and TSS loading varied to the plant were significantly higher than typical sanitary wastewater (both exceeding 1000 mg/L) on three of the days sampled. The plant reported heavy foaming and filamentous bacteria growth on those days, leading to high RAS chlorination.
- The plant seems to consider RAS chlorination when identifying target doses for disinfection.
- The particle size distribution results indicate a significant increase in solids sizes since 2005.

Appendix A
Sampling Results

SampleID Configuration: "Parameter-Location (abbreviated)-sample day"

Table A1: CDM Smith Sampling Results

Day	Sampling Dates	Time	Parameter	Sampling Location	Value	Value2	Units	SampleID	Contracting Party	Notes	Discard	Detection
1	6/29/2020	10:40	cBOD	Plant Influent	150		mg/L	cBOD-PI-01	NYEnvironmental	Samples from screen No.3(last from exit door)		
1	6/29/2020	9:40	cBOD	Primary Effluent	210		mg/L	cBOD-PE-01	NYEnvironmental	samples from trough No.2 (4th from the ending)		
1	6/29/2020	8:50	cBOD	Final Tank Effluent	4.3		mg/L	cBOD-FTE-01	NYEnvironmental	samples from last channels/final tank		
1	6/29/2020	8:00	cBOD	CCT Effluent	5.7		mg/L	cBOD-CCTE-01	NYEnvironmental	from small access hole at North end of the CCT's		
1	6/29/2020	10:40	Enterococcus	Plant Influent	2,737,500		MPN/100mL	EC-PI-01	NYEnvironmental	Samples from screen No.3(last from exit door)		
1	6/29/2020	10:40	pH	Plant Influent	6.86		-	pH-PI-01	MDE	Samples from screen No.3(last from exit door) Outside of QA/QC limits		
1	6/29/2020	10:40	Temperature	Plant Influent	26.9		C	T-PI-01	MDE	Samples from screen No.3(last from exit door)		
1	6/29/2020	10:40	Field TRC	Plant Influent	0.22		mg/L	FTRC-PI-01	MDE	Samples from screen No.3(last from exit door)		
1	6/29/2020	9:40	Enterococcus	Primary Effluent	706,800		MPN/100mL	EC-PE-01	NYEnvironmental	samples from trough No.2 (4th from the ending)		
1	6/29/2020	8:50	Enterococcus	Final Tank Effluent	217,600		MPN/100mL	EC-FTE-01	NYEnvironmental	samples from last channels/final tank		
1	6/29/2020	8:00	Enterococcus	CCT Effluent	910		MPN/100mL	EC-CCTE-01	NYEnvironmental	from small access hole at North end of the CCT's Not typical of CCT Effluent		
1	6/29/2020	8:50	Enterococcus	Final Tank Effluent	217,600		MPN/100mL	EC-FTE-01	NYEnvironmental	samples from last channels/final tank		
1	6/29/2020	10:40	Fecal Coliform	Plant Influent	4,150,000		MPN/100mL	FC-PI-01	NYEnvironmental	Samples from screen No.3(last from exit door)		
1	6/29/2020	9:40	pH	Primary Effluent	6.88		-	pH-PE-01	MDE	samples from trough No.2 (4th from the ending) Outside of QA/QC limits		
1	6/29/2020	9:40	Temperature	Primary Effluent	26.4		C	T-PE-01	MDE	samples from trough No.2 (4th from the ending)		
1	6/29/2020	9:40	Field TRC	Primary Effluent	0.01		mg/L	FTRC-PE-01	MDE	samples from trough No.2 (4th from the ending)		
1	6/29/2020	9:40	Fecal Coliform	Primary Effluent	12,100,000		MPN/100mL	FC-PE-01	NYEnvironmental	samples from trough No.2 (4th from the ending)		
1	6/29/2020	8:50	Fecal Coliform	Final Tank Effluent	866,000		MPN/100mL	FC-FTE-01	NYEnvironmental	samples from last channels/final tank		
1	6/29/2020	8:00	Fecal Coliform	CCT Effluent	75		MPN/100mL	FC-CCTE-01	NYEnvironmental	from small access hole at North end of the CCT's		
1	6/29/2020	8:50	Fecal Coliform	Final Tank Effluent	1,140,000		MPN/100mL	FC-FTE-01	NYEnvironmental	samples from last channels/final tank		
1	6/29/2020	8:50	pH	Final Tank Effluent	7.14		-	pH-FTE-01	MDE	samples from last channels/final tank Outside of QA/QC limits		
1	6/29/2020	8:50	Temperature	Final Tank Effluent	26.4		C	T-FTE-01	MDE	samples from last channels/final tank		
1	6/29/2020	8:50	Field TRC	Final Tank Effluent	0		mg/L	FTRC-FTE-01	MDE	samples from last channels/final tank		
1	6/29/2020	10:40	TSS	Plant Influent	1200		mg/L	TSS-PI-01	NYEnvironmental	Samples from screen No.3(last from exit door)		
1	6/29/2020	9:40	TSS	Primary Effluent	64		mg/L	TSS-PE-01	NYEnvironmental	samples from trough No.2 (4th from the ending) Not typical of Primary Effluent	x	
1	6/29/2020	8:50	TSS	Final Tank Effluent	7.3		mg/L	TSS-FTE-01	NYEnvironmental	samples from last channels/final tank		
1	6/29/2020	8:00	TSS	CCT Effluent	6.0		mg/L	TSS-CCTE-01	NYEnvironmental	from small access hole at North end of the CCT's		
1	6/29/2020	8:00	pH	CCT Effluent	7.07		-	pH-CCTE-01	MDE	from small access hole at North end of the CCT's Not typical of CCT Effluent		
1	6/29/2020	8:00	Temperature	CCT Effluent	28.4		C	T-CCTE-01	MDE	from small access hole at North end of the CCT's		
1	6/29/2020	8:00	Field TRC	CCT Effluent	0.38		mg/L	FTRC-CCTE-01	MDE	from small access hole at North end of the CCT's		
2	6/30/2020	9:55	cBOD	Plant Influent	1400		mg/L	cBOD-PI-02	NYEnvironmental	Samples from screen No.1(First from exit door)Not typical of Plant Influent	x	
2	6/30/2020	9:15	cBOD	Primary Effluent	180		mg/L	cBOD-PE-02	NYEnvironmental			
2	6/30/2020	8:25	cBOD	Final Tank Effluent	7.7		mg/L	cBOD-FTE-02	NYEnvironmental	samples from last channels/final tank		
2	6/30/2020	7:45	cBOD	CCT Effluent	12		mg/L	cBOD-CCTE-02	NYEnvironmental	from small access hole at North end of the CCT's		
2	6/30/2020	9:55	pH	Plant Influent	6.97	7.36	-	pH-PI-02	MDE	Samples from screen No.1(First from exit door) Outside of QA/QC limits		
2	6/30/2020	9:55	Temperature	Plant Influent	28	27.1	C	T-PI-02	MDE	Samples from screen No.1(First from exit door)		
2	6/30/2020	9:55	Field TRC	Plant Influent	2.04		mg/L	FTRC-PI-02	MDE	Samples from screen No.1(First from exit door)		
2	6/30/2020	9:55	Enterococcus	Plant Influent	268,200		MPN/100mL	EC-PI-02	NYEnvironmental	Samples from screen No.1(First from exit door) Not typical of Plant Influent		
2	6/30/2020	9:15	Enterococcus	Primary Effluent	633,000		MPN/100mL	EC-PE-02	NYEnvironmental	samples from trough No.2 (3rd from the ending)		
2	6/30/2020	8:25	Enterococcus	Final Tank Effluent	17,500		MPN/100mL	EC-FTE-02	NYEnvironmental	samples from last channels/final tank		
2	6/30/2020	8:25	Enterococcus	CCT Effluent	195		MPN/100mL	EC-CCTE-02	NYEnvironmental	from small access hole at North end of the CCT's		
2	6/30/2020	9:15	pH	Primary Effluent	7.07	7.33	-	pH-PE-02	MDE	samples from trough No.2 (3rd from the ending)		
2	6/30/2020	9:15	Temperature	Primary Effluent	25	24.8	C	T-PE-02	MDE	samples from trough No.2 (3rd from the ending)		
2	6/30/2020	9:15	Field TRC	Primary Effluent	0.01		mg/L	FTRC-PE-02	MDE	samples from trough No.2 (3rd from the ending)		
2	6/30/2020	7:45	Enterococcus	Final Tank Effluent	19,650		MPN/100mL	EC-FTE-02	NYEnvironmental	samples from last channels/final tank		
2	6/30/2020	9:55	Fecal Coliform	Plant Influent	7,070,000		MPN/100mL	FC-PI-02	NYEnvironmental	Samples from screen No.1(First from exit door)		
2	6/30/2020	9:15	Fecal Coliform	Primary Effluent	3,070,000		MPN/100mL	FC-PE-02	NYEnvironmental	samples from trough No.2 (3rd from the ending)		
2	6/30/2020	8:25	Fecal Coliform	Final Tank Effluent	1,380,000		MPN/100mL	FC-FTE-02	NYEnvironmental	samples from last channels/final tank		
2	6/30/2020	8:25	pH	Final Tank Effluent	7.54	7.88	-	pH-FTE-02	MDE	samples from last channels/final tank		
2	6/30/2020	8:25	Temperature	Final Tank Effluent	25	24.7	C	T-FTE-02	MDE	samples from last channels/final tank		
2	6/30/2020	8:25	Field TRC	Final Tank Effluent	0.08		mg/L	FTRC-FTE-02	MDE	samples from last channels/final tank		
2	6/30/2020	8:25	Fecal Coliform	CCT Effluent	3,850		MPN/100mL	FC-CCTE-02	NYEnvironmental	from small access hole at North end of the CCT's Not typical of CCT Effluent		

Day	Sampling Dates	Time	Parameter	Sampling Location	Value	Value2	Units	SampleID	Contracting Party	Notes	Discard	Detection
2	6/30/2020	8:25	Fecal Coliform	Final Tank Effluent	1,300,000		MPN/100mL	FC-FTE-02	NYEnvironmental	samples from last channels/final tank		
2	6/30/2020	9:55	TSS	Plant Influent	3,500		mg/L	TSS-PI-02	NYEnvironmental	Samples from screen No.1(First from exit door) Not typical of Plant Influent	x	
2	6/30/2020	9:15	TSS	Primary Effluent	60		mg/L	TSS-PE-02	NYEnvironmental	samples from trough No.2 (3rd from the ending)		
2	6/30/2020	7:45	pH	CCT Effluent	7.46	7.7	-	pH-CCTE-02	MDE	from small access hole at North end of the CCT's		
2	6/30/2020	7:45	Temperature	CCT Effluent	24.4	24.4	C	T-CCTE-02	MDE	from small access hole at North end of the CCT's		
2	6/30/2020	7:45	Field TRC	CCT Effluent	0.06		mg/L	FTRC-CCTE-02	MDE	from small access hole at North end of the CCT's		
2	6/30/2020	8:25	TSS	Final Tank Effluent	6.7		mg/L	TSS-FTE-02	NYEnvironmental	samples from last channels/final tank		
2	6/30/2020	7:45	TSS	CCT Effluent	8.0		mg/L	TSS-CCTE-02	NYEnvironmental	from small access hole at North end of the CCT's		
3	7/1/2020	9:33	cBOD	Plant Influent	1,700		mg/L	cBOD-PI-03	NYEnvironmental	Samples from screen No.2(the middle) Not typical of cBOD Plant influent	x	
3	7/1/2020	8:49	cBOD	Primary Effluent	180		mg/L	cBOD-PE-03	NYEnvironmental	samples from trough No.2 (2nd from the ending		
3	7/1/2020	9:33	pH	Plant Influent	7.05	7.38	-	pH-PI-03	MDE	Samples from screen No.2(the middle) Outside of QA/QC limits		
3	7/1/2020	9:33	Temperature	Plant Influent	26.9	26.3	C	T-PI-03	MDE	Samples from screen No.2(the middle)		
3	7/1/2020	9:33	Field TRC	Plant Influent	0.21		mg/L	FTRC-PI-03	MDE	Samples from screen No.2(the middle)		
3	7/1/2020	8:09	cBOD	Final Tank Effluent	4		mg/L	cBOD-FTE-03	NYEnvironmental	samples from last channels/final tank		<
3	7/1/2020	7:34	cBOD	CCT Effluent	4		mg/L	cBOD-CCTE-03	NYEnvironmental	from small access hole at North end of the CCT's		<
3	7/1/2020	9:33	Enterococcus	Plant Influent	1,093,500		MPN/100mL	EC-PI-03	NYEnvironmental	Samples from screen No.2(the middle)		
3	7/1/2020	8:49	Enterococcus	Primary Effluent	589,000		MPN/100mL	EC-PE-03	NYEnvironmental	samples from trough No.2 (2nd from the ending		
3	7/1/2020	8:49	pH	Primary Effluent	7.2	7.46	-	pH-PE-03	MDE	samples from trough No.2 (2nd from the ending)		
3	7/1/2020	8:49	Temperature	Primary Effluent	24.5	24.1	C	T-PE-03	MDE	samples from trough No.2 (2nd from the ending		
3	7/1/2020	8:49	Field TRC	Primary Effluent	0.11		mg/L	FTRC-PE-03	MDE	samples from trough No.2 (2nd from the ending		
3	7/1/2020	8:09	Enterococcus	Final Tank Effluent	37,700		MPN/100mL	EC-FTE-03	NYEnvironmental	samples from last channels/final tank		
3	7/1/2020	7:34	Enterococcus	CCT Effluent	188.5		MPN/100mL	EC-CCTE-03	NYEnvironmental	from small access hole at North end of the CCT's		
3	7/1/2020	8:09	Enterococcus	Final Tank Effluent	62,300		MPN/100mL	EC-FTE-03	NYEnvironmental	samples from last channels/final tank		
3	7/1/2020	9:33	Fecal Coliform	Plant Influent	5,600,000		MPN/100mL	FC-PI-03	NYEnvironmental	Samples from screen No.2(the middle)		
3	7/1/2020	8:09	pH	Final Tank Effluent	7.41	7.8	-	pH-FTE-03	MDE	samples from last channels/final tank		
3	7/1/2020	8:09	Temperature	Final Tank Effluent	24.6	24.7	C	T-FTE-03	MDE	samples from last channels/final tank		
3	7/1/2020	8:09	Field TRC	Final Tank Effluent	0.04		mg/L	FTRC-FTE-03	MDE	samples from last channels/final tank		
3	7/1/2020	8:49	Fecal Coliform	Primary Effluent	4,040,000		MPN/100mL	FC-PE-03	NYEnvironmental	samples from trough No.2 (2nd from the ending		
3	7/1/2020	8:09	Fecal Coliform	Final Tank Effluent	287,000		MPN/100mL	FC-FTE-03	NYEnvironmental	samples from last channels/final tank Not typical of Final Tank Effluent		
3	7/1/2020	7:34	Fecal Coliform	CCT Effluent	117		MPN/100mL	FC-CCTE-03	NYEnvironmental	from small access hole at North end of the CCT's		
3	7/1/2020	8:09	Fecal Coliform	Final Tank Effluent	5,230,000		MPN/100mL	FC-FTE-03	NYEnvironmental	samples from last channels/final tank Not typical of Final Tank Effluent		
3	7/1/2020	7:34	pH	CCT Effluent	7.41	7.75	-	pH-CCTE-03	MDE	from small access hole at North end of the CCT's		
3	7/1/2020	7:34	Temperature	CCT Effluent	23.5	23.7	C	T-CCTE-03	MDE	from small access hole at North end of the CCT's		
3	7/1/2020	7:34	Field TRC	CCT Effluent	0.38		mg/L	FTRC-CCTE-03	MDE	from small access hole at North end of the CCT's		
3	7/1/2020	9:33	TSS	Plant Influent	3,700		mg/L	TSS-PI-03	NYEnvironmental	Samples from screen No.2(the middle) Not typical of Plant Influent TSS	x	
3	7/1/2020	8:49	TSS	Primary Effluent	66		mg/L	TSS-PE-03	NYEnvironmental	samples from trough No.2 (2nd from the ending		
3	7/1/2020	8:09	TSS	Final Tank Effluent	10		mg/L	TSS-FTE-03	NYEnvironmental	samples from last channels/final tank		
3	7/1/2020	7:34	TSS	CCT Effluent	8		mg/L	TSS-CCTE-03	NYEnvironmental	from small access hole at North end of the CCT's		
4	7/7/2020	9:30	pH	Plant Influent	7.33	7.66	-	pH-PI-04	MDE	Samples from screen No.2(the middle)		
4	7/7/2020	9:30	Temperature	Plant Influent	27.7	26.2	C	T-PI-04	MDE	Samples from screen No.2(the middle)		
4	7/7/2020	9:30	Field TRC	Plant Influent	0.19		mg/L	FTRC-PI-04	MDE	Samples from screen No.2(the middle)		
4	7/7/2020	9:30	cBOD	Plant Influent	170		mg/L	cBOD-PI-04	NYEnvironmental	Samples from screen No.2(the middle)		
4	7/7/2020	8:59	cBOD	Primary Effluent	67		mg/L	cBOD-PE-04	NYEnvironmental	samples from trough No.2 (3rd from the ending)		
4	7/7/2020	8:15	cBOD	Final Tank Effluent	5		mg/L	cBOD-FTE-04	NYEnvironmental	Samples from last channels/final tank		
4	7/7/2020	7:40	cBOD	CCT Effluent	4.7		mg/L	cBOD-CCTE-04	NYEnvironmental	From small access hole at North end of the CCT's		
4	7/7/2020	8:59	pH	Primary Effluent	7.35	7.71	-	pH-PE-04	MDE	samples from trough No.2 (3rd from the ending)		
4	7/7/2020	8:59	Temperature	Primary Effluent	25.9	24.8	C	T-PE-04	MDE	samples from trough No.2 (3rd from the ending)		
4	7/7/2020	8:59	Field TRC	Primary Effluent	0.07		mg/L	FTRC-PE-04	MDE	samples from trough No.2 (3rd from the ending)		
4	7/7/2020	9:30	Enterococcus	Plant Influent	1,023,000		MPN/100mL	EC-PI-04	NYEnvironmental	Samples from screen No.2(the middle)		
4	7/7/2020	8:59	Enterococcus	Primary Effluent	698,000		MPN/100mL	EC-PE-04	NYEnvironmental	samples from trough No.2 (3rd from the ending)		
4	7/7/2020	8:15	Enterococcus	Final Tank Effluent	55,600		MPN/100mL	EC-FTE-04	NYEnvironmental	Samples from last channels/final tank		
4	7/7/2020	7:40	Enterococcus	CCT Effluent	232.5		MPN/100mL	EC-CCTE-04	NYEnvironmental	From small access hole at North end of the CCT's		
4	7/7/2020	8:15	pH	Final Tank Effluent	7.31	7.73	-	pH-FTE-04	MDE	Samples from last channels/final tank		
4	7/7/2020	8:15	Temperature	Final Tank Effluent	26	25.2	C	T-FTE-04	MDE	Samples from last channels/final tank		
4	7/7/2020	8:15	Field TRC	Final Tank Effluent	0.09		mg/L	FTRC-FTE-04	MDE	Samples from last channels/final tank		
4	7/7/2020	8:15	Enterococcus	Final Tank Effluent	57,250		MPN/100mL	EC-FTE-04	NYEnvironmental	Samples from last channels/final tank		
4	7/7/2020	9:30	Fecal Coliform	Plant Influent			MPN/100mL	FC-PI-04	NYEnvironmental	VOID Samples from screen No.2(the middle) Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
4	7/7/2020	8:59	Fecal Coliform	Primary Effluent			MPN/100mL	FC-PE-04	NYEnvironmental	VOID samples from trough No.2 (3rd from the ending) Issue with water bath having drifted in its setpoint, resulting in poor growth	X	

Day	Sampling Dates	Time	Parameter	Sampling Location	Value	Value2	Units	SampleID	Contracting Party	Notes	Discard	Detection
4	7/7/2020	8:15	Fecal Coliform	Final Tank Effluent			MPN/100mL	FC-FTE-04	NYEnvironmental	VOID Samples from last channels/final tank. Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
4	7/7/2020	7:40	pH	CCT Effluent	7.44	8.12	-	pH-CCTE-04	MDE	From small access hole at North end of the CCT's.		
4	7/7/2020	7:40	Temperature	CCT Effluent	25.3	24.5	C	T-CCTE-04	MDE	From small access hole at North end of the CCT's. I		
4	7/7/2020	7:40	Field TRC	CCT Effluent	0.29		mg/L	FTRC-CCTE-04	MDE	From small access hole at North end of the CCT's. I		
4	7/7/2020	7:40	Fecal Coliform	CCT Effluent			MPN/100mL	FC-CCTE-04	NYEnvironmental	VOID From small access hole at North end of the CCT's. Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
4	7/7/2020	8:15	Fecal Coliform	Final Tank Effluent			MPN/100mL	FC-FTE-04	NYEnvironmental	VOID Samples from last channels/final tank. Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
4	7/7/2020	9:30	TSS	Plant Influent	120		mg/L	TSS-PI-04	NYEnvironmental	Samples from screen No.2(the middle)		
4	7/7/2020	8:59	TSS	Primary Effluent	58		mg/L	TSS-PE-04	NYEnvironmental	samples from trough No.2 (3rd from the ending)		
4	7/7/2020	8:15	TSS	Final Tank Effluent	11		mg/L	TSS-FTE-04	NYEnvironmental	Samples from last channels/final tank		
4	7/7/2020	7:40	TSS	CCT Effluent	12		mg/L	TSS-CCTE-04	NYEnvironmental	From small access hole at North end of the CCT's		
5	7/8/2020	9:26	pH	Plant Influent	7.35	7.67	-	pH-PI-05	MDE	Samples from screen No.3(last from exit door)		
5	7/8/2020	9:26	Temperature	Plant Influent	27.6	27.2	C	T-PI-05	MDE	Samples from screen No.3(last from exit door)		
5	7/8/2020	9:26	Field TRC	Plant Influent	0.21		mg/L	FTRC-PI-05	MDE	Samples from screen No.3(last from exit door)		
5	7/8/2020	9:26	cBOD	Plant Influent	110		mg/L	cBOD-PI-05	NYEnvironmental	Samples from screen No.3(last from exit door)		
5	7/8/2020	8:45	cBOD	Primary Effluent	73		mg/L	cBOD-PE-05	NYEnvironmental	Samples from trough No.2 (2nd from the ending		
5	7/8/2020	8:45	pH	Primary Effluent	7.21	7.53	-	pH-PE-05	MDE	Samples from trough No.2 (2nd from the ending		
5	7/8/2020	8:45	Temperature	Primary Effluent	26.6	25.7	C	T-PE-05	MDE	Samples from trough No.2 (2nd from the ending		
5	7/8/2020	8:45	Field TRC	Primary Effluent	0.02		mg/L	FTRC-PE-05	MDE	Samples from trough No.2 (2nd from the ending		
5	7/8/2020	8:12	cBOD	Final Tank Effluent	4		mg/L	cBOD-FTE-05	NYEnvironmental	Samples from last channels/final tank		<
5	7/8/2020	7:39	cBOD	CCT Effluent	4		mg/L	cBOD-CCTE-05	NYEnvironmental	From small access hole at North end of the CCT's		<
5	7/8/2020	9:26	Enterococcus	Plant Influent	920,800		MPN/100mL	EC-PI-05	NYEnvironmental	Samples from screen No.3(last from exit door)		
5	7/8/2020	8:45	Enterococcus	Primary Effluent	517,200		MPN/100mL	EC-PE-05	NYEnvironmental	Samples from trough No.2 (2nd from the ending		
5	7/8/2020	8:12	pH	Final Tank Effluent	7.48	7.88	-	pH-FTE-05	MDE	Samples from last channels/final tank		
5	7/8/2020	8:12	Temperature	Final Tank Effluent	26.8	26.2	C	T-FTE-05	MDE	Samples from last channels/final tank		
5	7/8/2020	8:12	Field TRC	Final Tank Effluent	0.02		mg/L	FTRC-FTE-05	MDE	Samples from last channels/final tank		
5	7/8/2020	8:12	Enterococcus	Final Tank Effluent	162,750		MPN/100mL	EC-FTE-05	NYEnvironmental	samples from last channels/final tank Not typical of Final Tank Effluent		
5	7/8/2020	7:39	Enterococcus	CCT Effluent	49		MPN/100mL	EC-CCTE-05	NYEnvironmental	From small access hole at North end of the CCT's		
5	7/8/2020	8:12	Enterococcus	Final Tank Effluent	52,300		MPN/100mL	EC-FTE-05	NYEnvironmental	samples from last channels/final tank Not typical of Final Tank Effluent		
5	7/8/2020	9:26	Fecal Coliform	Plant Influent			MPN/100mL	FC-PI-05	NYEnvironmental	VOID Samples from screen No.3(last from exit door). Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
5	7/8/2020	7:39	pH	CCT Effluent	7.49	8.02	-	pH-CCTE-05	MDE	From small access hole at North end of the CCT's		
5	7/8/2020	7:39	Temperature	CCT Effluent	27	26.1	C	T-CCTE-05	MDE	From small access hole at North end of the CCT's		
5	7/8/2020	7:39	Field TRC	CCT Effluent	0.47		mg/L	FTRC-CCTE-05	MDE	From small access hole at North end of the CCT's		
5	7/8/2020	8:45	Fecal Coliform	Primary Effluent			MPN/100mL	FC-PE-05	NYEnvironmental	VOID Samples from trough No.2 (2nd from the ending). Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
5	7/8/2020	8:12	Fecal Coliform	Final Tank Effluent			MPN/100mL	FC-FTE-05	NYEnvironmental	VOID Samples from last channels/final tank. Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
5	7/8/2020	7:39	Fecal Coliform	CCT Effluent			MPN/100mL	FC-CCTE-05	NYEnvironmental	VOID From small access hole at North end of the CCT's. Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
5	7/8/2020	8:12	Fecal Coliform	Final Tank Effluent			MPN/100mL	FC-FTE-05	NYEnvironmental	VOID Samples from last channels/final tank. Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
5	7/8/2020	9:26	TSS	Plant Influent	120		mg/L	TSS-PI-05	NYEnvironmental	Samples from screen No.3(last from exit door)		
5	7/8/2020	8:45	TSS	Primary Effluent	57		mg/L	TSS-PE-05	NYEnvironmental	Samples from trough No.2 (2nd from the ending		
5	7/8/2020	8:12	TSS	Final Tank Effluent	8		mg/L	TSS-FTE-05	NYEnvironmental	Samples from last channels/final tank		
5	7/8/2020	7:39	TSS	CCT Effluent	6		mg/L	TSS-CCTE-05	NYEnvironmental	From small access hole at North end of the CCT's		
6	7/9/2020	9:19	pH	Plant Influent	7.38	7.76	-	pH-PI-06	MDE	Samples from screen No.1(First from exit door)		
6	7/9/2020	9:19	Temperature	Plant Influent	27.6	26.8	C	T-PI-06	MDE	Samples from screen No.1(First from exit door)		
6	7/9/2020	9:19	Field TRC	Plant Influent	0.19		mg/L	FTRC-PI-06	MDE	Samples from screen No.1(First from exit door)		
6	7/9/2020	8:43	pH	Primary Effluent	7.37	7.68	-	pH-PE-06	MDE	Samples from trough No.2 (3rd from the ending)		
6	7/9/2020	8:43	Temperature	Primary Effluent	26.1	25.2	C	T-PE-06	MDE	Samples from trough No.2 (3rd from the ending)		
6	7/9/2020	8:43	Field TRC	Primary Effluent	0.02		mg/L	FTRC-PE-06	MDE	Samples from trough No.2 (3rd from the ending)		
6	7/9/2020	9:19	cBOD	Plant Influent	160		mg/L	cBOD-PI-06	NYEnvironmental	Samples from screen No.1(First from exit door)		

Day	Sampling Dates	Time	Parameter	Sampling Location	Value	Value2	Units	SampleID	Contracting Party	Notes	Discard	Detection
6	7/9/2020	8:43	cBOD	Primary Effluent	98		mg/L	cBOD-PE-06	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
6	7/9/2020	8:15	cBOD	Final Tank Effluent	4.9		mg/L	cBOD-FTE-06	NYEnvironmental	Samples from last channels/final tank		
6	7/9/2020	7:42	cBOD	CCT Effluent	4		mg/L	cBOD-CCTE-06	NYEnvironmental	From small access hole at North end of the CCT's		<
6	7/9/2020	8:15	pH	Final Tank Effluent	7.42	7.81	-	pH-FTE-06	MDE	Samples from last channels/final tank		
6	7/9/2020	8:15	Temperature	Final Tank Effluent	26.4	25.5	C	T-FTE-06	MDE	Samples from last channels/final tank		
6	7/9/2020	8:15	Field TRC	Final Tank Effluent	0.22		mg/L	FTRC-FTE-06	MDE	Samples from last channels/final tank		
6	7/9/2020	9:19	Enterococcus	Plant Influent	1,093,500		MPN/100mL	EC-PI-06	NYEnvironmental	Samples from screen No.1(First from exit door)		
6	7/9/2020	8:43	Enterococcus	Primary Effluent	930,000		MPN/100mL	EC-PE-06	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
6	7/9/2020	8:15	Enterococcus	Final Tank Effluent	29,700		MPN/100mL	EC-FTE-06	NYEnvironmental	Samples from last channels/final tank		
6	7/9/2020	7:42	Enterococcus	CCT Effluent	49		MPN/100mL	EC-CCTE-06	NYEnvironmental	From small access hole at North end of the CCT's		
6	7/9/2020	7:42	pH	CCT Effluent	7.5	8.08	-	pH-CCTE-06	MDE	From small access hole at North end of the CCT's		
6	7/9/2020	7:42	Temperature	CCT Effluent	26.9	26.4	C	T-CCTE-06	MDE	From small access hole at North end of the CCT's		
6	7/9/2020	7:42	Field TRC	CCT Effluent	0.33		mg/L	FTRC-CCTE-06	MDE	From small access hole at North end of the CCT's		
6	7/9/2020	8:15	Enterococcus	Final Tank Effluent	39,700		MPN/100mL	EC-FTE-06	NYEnvironmental	Samples from last channels/final tank		
6	7/9/2020	9:19	Fecal Coliform	Plant Influent			MPN/100mL	FC-PI-06	NYEnvironmental	VOID Samples from screen No.1(First from exit door). Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
6	7/9/2020	8:43	Fecal Coliform	Primary Effluent			MPN/100mL	FC-PE-06	NYEnvironmental	VOID Samples from trough No.2 (3rd from the ending). Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
6	7/9/2020	8:15	Fecal Coliform	Final Tank Effluent			MPN/100mL	FC-FTE-06	NYEnvironmental	VOID Samples from last channels/final tank. Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
6	7/9/2020	7:42	Fecal Coliform	CCT Effluent			MPN/100mL	FC-CCTE-06	NYEnvironmental	VOID From small access hole at North end of the CCT's. Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
6	7/9/2020	8:15	Fecal Coliform	Final Tank Effluent			MPN/100mL	FC-FTE-06	NYEnvironmental	VOID Samples from last channels/final tank. Issue with water bath having drifted in its setpoint, resulting in poor growth	X	
6	7/9/2020	9:19	TSS	Plant Influent	98		mg/L	TSS-PI-06	NYEnvironmental	Samples from screen No.1(First from exit door)		
6	7/9/2020	8:43	TSS	Primary Effluent	45		mg/L	TSS-PE-06	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
6	7/9/2020	8:15	TSS	Final Tank Effluent	4		mg/L	TSS-FTE-06	NYEnvironmental	Samples from last channels/final tank		
6	7/9/2020	7:42	TSS	CCT Effluent	4		mg/L	TSS-CCTE-06	NYEnvironmental	From small access hole at North end of the CCT's		
6	7/9/2020	10:20	Particle Size Distribution XAD	Aeration Tank Effluent			-	XAD-ATE-06	Manhattan College	Sample location I.D. # PR327299		
7	7/10/2020	9:10	pH	Plant Influent	7.21	7.55	-	pH-PI-07	MDE	Samples from screen No.2(the middle)		
7	7/10/2020	9:10	Temperature	Plant Influent	26.9	26.6	C	T-PI-07	MDE	Samples from screen No.2(the middle)		
7	7/10/2020	9:10	Field TRC	Plant Influent	0.63		mg/L	FTRC-PI-07	MDE	Samples from screen No.2(the middle)		
7	7/10/2020	8:38	pH	Primary Effluent	7.23	7.53	-	pH-PE-07	MDE	Samples from trough No.2 (2nd from the ending		
7	7/10/2020	8:38	Temperature	Primary Effluent	26.4	25.9	C	T-PE-07	MDE	Samples from trough No.2 (2nd from the ending		
7	7/10/2020	8:38	Field TRC	Primary Effluent	0.04		mg/L	FTRC-PE-07	MDE	Samples from trough No.2 (2nd from the ending		
7	7/10/2020	9:10	cBOD	Plant Influent			mg/L	cBOD-PI-07	NYEnvironmental	Samples from screen No.2(the middle). Out of holding time	X	
7	7/10/2020	8:10	pH	Final Tank Effluent	7.41	7.79	-	pH-FTE-07	MDE	Samples from last channels/final tank.		
7	7/10/2020	8:10	Temperature	Final Tank Effluent	26.1	25.8	C	T-FTE-07	MDE	Samples from last channels/final tank		
7	7/10/2020	8:10	Field TRC	Final Tank Effluent	0.13		mg/L	FTRC-FTE-07	MDE	Samples from last channels/final tank		
7	7/10/2020	8:38	cBOD	Primary Effluent			mg/L	cBOD-PE-07	NYEnvironmental	Samples from trough No.2 (2nd from the ending). Out of holding time	X	
7	7/10/2020	8:10	cBOD	Final Tank Effluent			mg/L	cBOD-FTE-07	NYEnvironmental	Samples from last channels/final tank. Out of holding time	X	
7	7/10/2020	7:46	cBOD	CCT Effluent			mg/L	cBOD-CCTE-07	NYEnvironmental	From small access hole at North end of the CCT's. Out of holding time	X	
7	7/10/2020	9:10	Enterococcus	Plant Influent	1,244,500		MPN/100mL	EC-PI-07	NYEnvironmental	Samples from screen No.2(the middle)		
7	7/10/2020	7:46	pH	CCT Effluent	7.49	8.04	-	pH-CCTE-07	MDE	From small access hole at North end of the CCT's		
7	7/10/2020	7:46	Temperature	CCT Effluent	26.5	26	C	T-CCTE-07	MDE	From small access hole at North end of the CCT's		
7	7/10/2020	7:46	Field TRC	CCT Effluent	0.58		mg/L	FTRC-CCTE-07	MDE	From small access hole at North end of the CCT's		
7	7/10/2020	8:38	Enterococcus	Primary Effluent	648,800		MPN/100mL	EC-PE-07	NYEnvironmental	Samples from trough No.2 (2nd from the ending		
7	7/10/2020	8:10	Enterococcus	Final Tank Effluent	6,050		MPN/100mL	EC-FTE-07	NYEnvironmental	Samples from last channels/final tank		
7	7/10/2020	7:46	Enterococcus	CCT Effluent	5		MPN/100mL	EC-CCTE-07	NYEnvironmental	From small access hole at North end of the CCT's		<
7	7/10/2020	8:10	Enterococcus	Final Tank Effluent	9,250		MPN/100mL	EC-FTE-07	NYEnvironmental	Samples from last channels/final tank		
7	7/10/2020	9:10	Fecal Coliform	Plant Influent	1,450,000		MPN/100mL	FC-PI-07	NYEnvironmental	Samples from screen No.2(the middle)		
7	7/10/2020	8:38	Fecal Coliform	Primary Effluent	2,590,000		MPN/100mL	FC-PE-07	NYEnvironmental	Samples from trough No.2 (2nd from the ending		
7	7/10/2020	8:10	Fecal Coliform	Final Tank Effluent	72,500		MPN/100mL	FC-FTE-07	NYEnvironmental	Samples from last channels/final tank		
7	7/10/2020	7:46	Fecal Coliform	CCT Effluent	94.5		MPN/100mL	FC-CCTE-07	NYEnvironmental	From small access hole at North end of the CCT's		
7	7/10/2020	8:10	Fecal Coliform	Final Tank Effluent	83,200		MPN/100mL	FC-FTE-07	NYEnvironmental	Samples from last channels/final tank		
7	7/10/2020	9:10	TSS	Plant Influent			mg/L	TSS-PI-07	NYEnvironmental	Samples from screen No.2(the middle)		
7	7/10/2020	8:38	TSS	Primary Effluent			mg/L	TSS-PE-07	NYEnvironmental	Samples from trough No.2 (2nd from the ending		
7	7/10/2020	8:10	TSS	Final Tank Effluent			mg/L	TSS-FTE-07	NYEnvironmental	Samples from last channels/final tank		
7	7/10/2020	7:46	TSS	CCT Effluent			mg/L	TSS-CCTE-07	NYEnvironmental	From small access hole at North end of the CCT's		
8	7/13/2020	9:18	pH	Plant Influent	7.26	7.54	-	pH-PI-08	MDE	Samples from screen No.3(last from exit door)		
8	7/13/2020	9:18	Temperature	Plant Influent	21.9	25.9	C	T-PI-08	MDE	Samples from screen No.3(last from exit door)		
8	7/13/2020	9:18	Field TRC	Plant Influent	0.08		mg/L	FTRC-PI-08	MDE	Samples from screen No.3(last from exit door)		

Day	Sampling Dates	Time	Parameter	Sampling Location	Value	Value2	Units	SampleID	Contracting Party	Notes	Discard	Detection
8	7/13/2020	8:48	pH	Primary Effluent	7.21	7.51	-	pH-PE-08	MDE	Samples from trough No.2 (3rd from the ending)		
8	7/13/2020	8:48	Temperature	Primary Effluent	22.8	24.6	C	T-PE-08	MDE	Samples from trough No.2 (3rd from the ending)		
8	7/13/2020	8:48	Field TRC	Primary Effluent	0		mg/L	FTRC-PE-08	MDE	Samples from trough No.2 (3rd from the ending)		
8	7/13/2020	8:19	pH	Final Tank Effluent	7.43	7.77	-	pH-FTE-08	MDE	Samples from last channels/final tank		
8	7/13/2020	8:19	Temperature	Final Tank Effluent	24.1	25	C	T-FTE-08	MDE	Samples from last channels/final tank		
8	7/13/2020	8:19	Field TRC	Final Tank Effluent	0.1		mg/L	FTRC-FTE-08	MDE	Samples from last channels/final tank		
8	7/13/2020	9:18	cBOD	Plant Influent	200		mg/L	cBOD-PI-08	NYEnvironmental	Samples from screen No.3(last from exit door)		
8	7/13/2020	8:48	cBOD	Primary Effluent	250		mg/L	cBOD-PE-08	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
8	7/13/2020	8:19	cBOD	Final Tank Effluent	4		mg/L	cBOD-FTE-08	NYEnvironmental	Samples from last channels/final tank		<
8	7/13/2020	7:45	pH	CCT Effluent	7.38	7.87	-	pH-CCTE-08	MDE	From small access hole at North end of the CCT's		
8	7/13/2020	7:45	Temperature	CCT Effluent	23.9	25.5	C	T-CCTE-08	MDE	From small access hole at North end of the CCT's		
8	7/13/2020	7:45	Field TRC	CCT Effluent	0.59		mg/L	FTRC-CCTE-08	MDE	From small access hole at North end of the CCT's		
8	7/13/2020	7:45	cBOD	CCT Effluent	4		mg/L	cBOD-CCTE-08	NYEnvironmental	From small access hole at North end of the CCT's		<
8	7/13/2020	9:18	Enterococcus	Plant Influent	1,892,000		MPN/100mL	EC-PI-08	NYEnvironmental	Samples from screen No.3(last from exit door)		
8	7/13/2020	8:48	Enterococcus	Primary Effluent	782,500		MPN/100mL	EC-PE-08	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
8	7/13/2020	8:19	Enterococcus	Final Tank Effluent	2,050		MPN/100mL	EC-FTE-08	NYEnvironmental	Samples from last channels/final tank		
8	7/13/2020	7:45	Enterococcus	CCT Effluent	5		MPN/100mL	EC-CCTE-08	NYEnvironmental	From small access hole at North end of the CCT's		
8	7/13/2020	8:19	Enterococcus	Final Tank Effluent	3,700		MPN/100mL	EC-FTE-08	NYEnvironmental	Samples from last channels/final tank		
8	7/13/2020	9:18	Fecal Coliform	Plant Influent	6,500,000		MPN/100mL	FC-PI-08	NYEnvironmental	Samples from screen No.3(last from exit door)		
8	7/13/2020	8:48	Fecal Coliform	Primary Effluent	4,330,000		MPN/100mL	FC-PE-08	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
8	7/13/2020	8:19	Fecal Coliform	Final Tank Effluent	4,800		MPN/100mL	FC-FTE-08	NYEnvironmental	samples from last channels/final tank Not typical of Final Tank Effluent		
8	7/13/2020	7:45	Fecal Coliform	CCT Effluent	26		MPN/100mL	FC-CCTE-08	NYEnvironmental	From small access hole at North end of the CCT's		
8	7/13/2020	8:19	Fecal Coliform	Final Tank Effluent	15,800		MPN/100mL	FC-FTE-08	NYEnvironmental	samples from last channels/final tank Not typical of Final Tank Effluent		
8	7/13/2020	9:18	TSS	Plant Influent	110		mg/L	TSS-PI-08	NYEnvironmental	Samples from screen No.3(last from exit door)		
8	7/13/2020	8:48	TSS	Primary Effluent	98		mg/L	TSS-PE-08	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
8	7/13/2020	8:19	TSS	Final Tank Effluent	6		mg/L	TSS-FTE-08	NYEnvironmental	Samples from last channels/final tank		
8	7/13/2020	7:45	TSS	CCT Effluent	3.3		mg/L	TSS-CCTE-08	NYEnvironmental	From small access hole at North end of the CCT's		
8	7/13/2020	10:00	Particle Size Distribution XAD	Aeration Tank Effluent			-	XAD-ATE-08	Manhattan College	Sample location I.D. # PR327299		
9	7/14/2020	9:14	pH	Plant Influent	7.23	7.53	-	pH-PI-09	MDE	Samples from screen No.1(First from exit door)		
9	7/14/2020	9:14	Temperature	Plant Influent	25.1	25.1	C	T-PI-09	MDE	Samples from screen No.1(First from exit door)		
9	7/14/2020	9:14	Field TRC	Plant Influent	0.12		mg/L	FTRC-PI-09	MDE	Samples from screen No.1(First from exit door)		
9	7/14/2020	8:45	pH	Primary Effluent	7.28	7.62	-	pH-PE-09	MDE	Samples from trough No.2 (3rd from the ending)		
9	7/14/2020	8:45	Temperature	Primary Effluent	19.7	23.1	C	T-PE-09	MDE	Samples from trough No.2 (3rd from the ending)		
9	7/14/2020	8:45	Field TRC	Primary Effluent	0		mg/L	FTRC-PE-09	MDE	Samples from trough No.2 (3rd from the ending)		
9	7/14/2020	8:08	pH	Final Tank Effluent	7.53	7.88	-	pH-FTE-09	MDE	Samples from last channels/final tank		
9	7/14/2020	8:08	Temperature	Final Tank Effluent	22.2	24.1	C	T-FTE-09	MDE	Samples from last channels/final tank		
9	7/14/2020	8:08	Field TRC	Final Tank Effluent	0.02		mg/L	FTRC-FTE-09	MDE	Samples from last channels/final tank		
9	7/14/2020	7:43	pH	CCT Effluent	7.64	8.1	-	pH-CCTE-09	MDE	From small access hole at North end of the CCT's		
9	7/14/2020	7:43	Temperature	CCT Effluent	23.8	23.9	C	T-CCTE-09	MDE	From small access hole at North end of the CCT's		
9	7/14/2020	7:43	Field TRC	CCT Effluent	0.63		mg/L	FTRC-CCTE-09	MDE	From small access hole at North end of the CCT's		
9	7/14/2020	9:14	cBOD	Plant Influent	280		mg/L	cBOD-PI-09	NYEnvironmental	Samples from screen No.1(First from exit door)		
9	7/14/2020	8:45	cBOD	Primary Effluent	88		mg/L	cBOD-PE-09	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
9	7/14/2020	8:08	cBOD	Final Tank Effluent	4		mg/L	cBOD-FTE-09	NYEnvironmental	Samples from last channels/final tank		<
9	7/14/2020	7:43	cBOD	CCT Effluent	4		mg/L	cBOD-CCTE-09	NYEnvironmental	From small access hole at North end of the CCT's		<
9	7/14/2020	9:14	Enterococcus	Plant Influent	1,377,500		MPN/100mL	EC-PI-09	NYEnvironmental	Samples from screen No.1(First from exit door)		
9	7/14/2020	8:45	Enterococcus	Primary Effluent	550,000		MPN/100mL	EC-PE-09	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
9	7/14/2020	8:08	Enterococcus	Final Tank Effluent	10,650		MPN/100mL	EC-FTE-09	NYEnvironmental	Samples from last channels/final tank		
9	7/14/2020	7:43	Enterococcus	CCT Effluent	5		MPN/100mL	EC-CCTE-09	NYEnvironmental	From small access hole at North end of the CCT's		
9	7/14/2020	8:08	Enterococcus	Final Tank Effluent	8,050		MPN/100mL	EC-FTE-09	NYEnvironmental	Samples from last channels/final tank		
9	7/14/2020	9:14	Fecal Coliform	Plant Influent			MPN/100mL	FC-PI-09	NYEnvironmental	VOID Samples from screen No.1(First from exit door)	X	
9	7/14/2020	8:45	Fecal Coliform	Primary Effluent			MPN/100mL	FC-PE-09	NYEnvironmental	VOID Samples from trough No.2 (3rd from the ending)	X	
9	7/14/2020	8:08	Fecal Coliform	Final Tank Effluent			MPN/100mL	FC-FTE-09	NYEnvironmental	VOID Samples from last channels/final tank	X	
9	7/14/2020	7:43	Fecal Coliform	CCT Effluent			MPN/100mL	FC-CCTE-09	NYEnvironmental	VOID From small access hole at North end of the CCT's	X	
9	7/14/2020	8:08	Fecal Coliform	Final Tank Effluent			MPN/100mL	FC-FTE-09	NYEnvironmental	VOID Samples from last channels/final tank	X	
9	7/14/2020	9:14	TSS	Plant Influent	43		mg/L	TSS-PI-09	NYEnvironmental	Samples from screen No.1(First from exit door)		
9	7/14/2020	8:45	TSS	Primary Effluent	120		mg/L	TSS-PE-09	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
9	7/14/2020	8:08	TSS	Final Tank Effluent	5.3		mg/L	TSS-FTE-09	NYEnvironmental	Samples from last channels/final tank		
9	7/14/2020	7:43	TSS	CCT Effluent	4.7		mg/L	TSS-CCTE-09	NYEnvironmental	From small access hole at North end of the CCT's		
10	7/15/2020	9:05	pH	Plant Influent	7.33	7.66	-	pH-PI-10	MDE	Samples from screen No.2(the middle)		
10	7/15/2020	9:05	Temperature	Plant Influent	23.3	25.5	C	T-PI-10	MDE	Samples from screen No.2(the middle)		
10	7/15/2020	9:05	Field TRC	Plant Influent	0.15		mg/L	FTRC-PI-10	MDE	Samples from screen No.2(the middle)		
10	7/15/2020	8:40	pH	Primary Effluent	7.29	7.61	-	pH-PE-10	MDE	Samples from trough No.2 (2nd from the ending		
10	7/15/2020	8:40	Temperature	Primary Effluent	22.9	23.4	C	T-PE-10	MDE	Samples from trough No.2 (2nd from the ending		
10	7/15/2020	8:40	Field TRC	Primary Effluent	0.02		mg/L	FTRC-PE-10	MDE	Samples from trough No.2 (2nd from the ending		
10	7/15/2020	8:10	pH	Final Tank Effluent	7.44	7.77	-	pH-FTE-10	MDE	Samples from last channels/final tank		

Day	Sampling Dates	Time	Parameter	Sampling Location	Value	Value2	Units	SampleID	Contracting Party	Notes	Discard	Detection
10	7/15/2020	8:10	Temperature	Final Tank Effluent	23.9	24.7	C	T-FTE-10	MDE	Samples from last channels/final tank		
10	7/15/2020	8:10	Field TRC	Final Tank Effluent	0.07		mg/L	FTRC-FTE-10	MDE	Samples from last channels/final tank		
10	7/15/2020	7:42	pH	CCT Effluent	7.6	8.06	-	pH-CCTE-10	MDE	From small access hole at North end of the CCT's		
10	7/15/2020	7:42	Temperature	CCT Effluent	24.1	24.7	C	T-CCTE-10	MDE	From small access hole at North end of the CCT's		
10	7/15/2020	7:42	Field TRC	CCT Effluent	0.47		mg/L	FTRC-CCTE-10	MDE	From small access hole at North end of the CCT's		
10	7/15/2020	9:05	cBOD	Plant Influent	170		mg/L	cBOD-PI-10	NYEnvironmental	Samples from screen No.2(the middle)		
10	7/15/2020	8:40	cBOD	Primary Effluent	140		mg/L	cBOD-PE-10	NYEnvironmental	Samples from trough No.2 (2nd from the ending		
10	7/15/2020	8:10	cBOD	Final Tank Effluent	4		mg/L	cBOD-FTE-10	NYEnvironmental	Samples from last channels/final tank		<
10	7/15/2020	7:42	cBOD	CCT Effluent	4		mg/L	cBOD-CCTE-10	NYEnvironmental	From small access hole at North end of the CCT's		<
10	7/15/2020	9:05	Enterococcus	Plant Influent	892,500		MPN/100mL	EC-PI-10	NYEnvironmental	Samples from screen No.2(the middle)		
10	7/15/2020	8:40	Enterococcus	Primary Effluent	307,600		MPN/100mL	EC-PE-10	NYEnvironmental	Samples from trough No.2 (2nd from the ending		
10	7/15/2020	8:10	Enterococcus	Final Tank Effluent	25,600		MPN/100mL	EC-FTE-10	NYEnvironmental	Samples from last channels/final tank		
10	7/15/2020	7:42	Enterococcus	CCT Effluent	10		MPN/100mL	EC-CCTE-10	NYEnvironmental	From small access hole at North end of the CCT's		
10	7/15/2020	8:10	Enterococcus	Final Tank Effluent	17,950		MPN/100mL	EC-FTE-10	NYEnvironmental	Samples from last channels/final tank		
10	7/15/2020	9:05	Fecal Coliform	Plant Influent			MPN/100mL	FC-PI-10	NYEnvironmental	Samples from screen No.2(the middle) VOID	X	
10	7/15/2020	8:40	Fecal Coliform	Primary Effluent			MPN/100mL	FC-PE-10	NYEnvironmental	Samples from trough No.2 (2nd from the ending VOID	X	
10	7/15/2020	8:10	Fecal Coliform	Final Tank Effluent			MPN/100mL	FC-FTE-10	NYEnvironmental	Samples from last channels/final tank VOID	X	
10	7/15/2020	7:42	Fecal Coliform	CCT Effluent			MPN/100mL	FC-CCTE-10	NYEnvironmental	From small access hole at North end of the CCT's VOID	X	
10	7/15/2020	8:10	Fecal Coliform	Final Tank Effluent			MPN/100mL	FC-FTE-10	NYEnvironmental	Samples from last channels/final tank VOID	X	
10	7/15/2020	9:05	TSS	Plant Influent	130		mg/L	TSS-PI-10	NYEnvironmental	Samples from screen No.2(the middle)		
10	7/15/2020	8:40	TSS	Primary Effluent	43		mg/L	TSS-PE-10	NYEnvironmental	Samples from trough No.2 (2nd from the ending		
10	7/15/2020	8:10	TSS	Final Tank Effluent	6		mg/L	TSS-FTE-10	NYEnvironmental	Samples from last channels/final tank		
10	7/15/2020	7:42	TSS	CCT Effluent	5.3		mg/L	TSS-CCTE-10	NYEnvironmental	From small access hole at North end of the CCT's		
11	7/16/2020	8:59	pH	Plant Influent	7.22	7.64	-	pH-PI-11	MDE	Samples from screen No.3(last from exit door)		
11	7/16/2020	8:59	Temperature	Plant Influent	23.1	24.4	C	T-PI-11	MDE	Samples from screen No.3(last from exit door)		
11	7/16/2020	8:59	Field TRC	Plant Influent	0.19	0.22	mg/L	FTRC-PI-11	MDE	Samples from screen No.3(last from exit door). Note that Khalid took 2 readings for TRC (0.19 and 0.22) at the plant influent as it was slightly elevated from earlier this week.		
11	7/16/2020	8:30	pH	Primary Effluent	7.23	7.63	-	pH-PE-11	MDE	Samples from trough No.2 (3rd from the ending)		
11	7/16/2020	8:30	Temperature	Primary Effluent	22.5	23.2	C	T-PE-11	MDE	Samples from trough No.2 (3rd from the ending)		
11	7/16/2020	8:30	Field TRC	Primary Effluent	0		mg/L	FTRC-PE-11	MDE	Samples from trough No.2 (3rd from the ending)		
11	7/16/2020	7:55	pH	Final Tank Effluent	7.44	7.84	-	pH-FTE-11	MDE	Samples from last channels/final tank		
11	7/16/2020	7:55	Temperature	Final Tank Effluent	21.4	23.9	C	T-FTE-11	MDE	Samples from last channels/final tank		
11	7/16/2020	7:55	Field TRC	Final Tank Effluent	0.02		mg/L	FTRC-FTE-11	MDE	Samples from last channels/final tank		
11	7/16/2020	7:27	pH	CCT Effluent	7.54	8.06	-	pH-CCTE-11	MDE	From small access hole at North end of the CCT's		
11	7/16/2020	7:27	Temperature	CCT Effluent	23.4	23.7	C	T-CCTE-11	MDE	From small access hole at North end of the CCT's		
11	7/16/2020	7:27	Field TRC	CCT Effluent	0.52		mg/L	FTRC-CCTE-11	MDE	From small access hole at North end of the CCT's		
11	7/16/2020	8:59	cBOD	Plant Influent	280		mg/L	cBOD-PI-11	NYEnvironmental	Samples from screen No.3(last from exit door)		
11	7/16/2020	8:30	cBOD	Primary Effluent	92		mg/L	cBOD-PE-11	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
11	7/16/2020	7:55	cBOD	Final Tank Effluent	4		mg/L	cBOD-FTE-11	NYEnvironmental	Samples from last channels/final tank		<
11	7/16/2020	7:27	cBOD	CCT Effluent	4		mg/L	cBOD-CCTE-11	NYEnvironmental	From small access hole at North end of the CCT's		<
11	7/16/2020	8:59	Enterococcus	Plant Influent	902,800		MPN/100mL	EC-PI-11	NYEnvironmental	Samples from screen No.3(last from exit door)		
11	7/16/2020	8:30	Enterococcus	Primary Effluent	365,400		MPN/100mL	EC-PE-11	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
11	7/16/2020	7:55	Enterococcus	Final Tank Effluent	67,700		MPN/100mL	EC-FTE-11	NYEnvironmental	Samples from last channels/final tank		
11	7/16/2020	7:27	Enterococcus	CCT Effluent	20.5		MPN/100mL	EC-CCTE-11	NYEnvironmental	From small access hole at North end of the CCT's		
11	7/16/2020		Enterococcus	Final Tank Effluent	55,950		MPN/100mL	EC-FTE-11	NYEnvironmental	Samples from last channels/final tank		
11	7/16/2020	8:59	Fecal Coliform	Plant Influent	2,310,000		MPN/100mL	FC-PI-11	NYEnvironmental	Samples from screen No.3(last from exit door)		
11	7/16/2020	8:30	Fecal Coliform	Primary Effluent	2,050,000		MPN/100mL	FC-PE-11	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
11	7/16/2020	7:55	Fecal Coliform	Final Tank Effluent	274,000		MPN/100mL	FC-FTE-11	NYEnvironmental	Samples from last channels/final tank		
11	7/16/2020	7:27	Fecal Coliform	CCT Effluent	42.5		MPN/100mL	FC-CCTE-11	NYEnvironmental	From small access hole at North end of the CCT's		
11	7/16/2020	7:55	Fecal Coliform	Final Tank Effluent	205,000		MPN/100mL	FC-FTE-11	NYEnvironmental	Samples from last channels/final tank		
11	7/16/2020	8:59	TSS	Plant Influent	140		mg/L	TSS-PI-11	NYEnvironmental	Samples from screen No.3(last from exit door)		
11	7/16/2020	8:30	TSS	Primary Effluent	44		mg/L	TSS-PE-11	NYEnvironmental	Samples from trough No.2 (3rd from the ending)		
11	7/16/2020	7:55	TSS	Final Tank Effluent	6.5		mg/L	TSS-FTE-11	NYEnvironmental	Samples from last channels/final tank		
11	7/16/2020	7:27	TSS	CCT Effluent	4		mg/L	TSS-CCTE-11	NYEnvironmental	From small access hole at North end of the CCT's		
12	7/17/2020	9:36	pH	Plant Influent	7.35	7.67	-	pH-PI-12	MDE	Samples from screen No.1(First from exit door)		
12	7/17/2020	9:36	Temperature	Plant Influent	22.7	24.8	C	T-PI-12	MDE	Samples from screen No.1(First from exit door)		
12	7/17/2020	9:36	Field TRC	Plant Influent	0.17		mg/L	FTRC-PI-12	MDE	Samples from screen No.1(First from exit door)		
12	7/17/2020	8:58	pH	Primary Effluent	7.13	7.45	-	pH-PE-12	MDE	Samples from trough No.2 (2nd from the ending)		
12	7/17/2020	8:58	Temperature	Primary Effluent	22.9	23.3	C	T-PE-12	MDE	Samples from trough No.2 (2nd from the ending)		
12	7/17/2020	8:58	Field TRC	Primary Effluent	0.04		mg/L	FTRC-PE-12	MDE	Samples from trough No.2 (2nd from the ending)		
12	7/17/2020	8:30	pH	Final Tank Effluent	7.53	7.88	-	pH-FTE-12	MDE	Samples from last channels/final tank		
12	7/17/2020	8:30	Temperature	Final Tank Effluent	24	24.1	C	T-FTE-12	MDE	Samples from last channels/final tank		
12	7/17/2020	8:30	Field TRC	Final Tank Effluent	0.04		mg/L	FTRC-FTE-12	MDE	Samples from last channels/final tank		
12	7/17/2020	7:50	pH	CCT Effluent	7.53	8.07	-	pH-CCTE-12	MDE	From small access hole at North end of the CCT's		
12	7/17/2020	7:50	Temperature	CCT Effluent	23.6	23.8	C	T-CCTE-12	MDE	From small access hole at North end of the CCT's		
12	7/17/2020	7:50	Field TRC	CCT Effluent	0.48		mg/L	FTRC-CCTE-12	MDE	From small access hole at North end of the CCT's		

Day	Sampling Dates	Time	Parameter	Sampling Location	Value	Value2	Units	SampleID	Contracting Party	Notes	Discard	Detection
12	7/17/2020		cBOD	Plant Influent	200		mg/L	cBOD-PI-12	NYEnvironmental			
12	7/17/2020		cBOD	Primary Effluent	180		mg/L	cBOD-PE-12	NYEnvironmental			
12	7/17/2020		cBOD	Final Tank Effluent	4		mg/L	cBOD-FTE-12	NYEnvironmental			<
12	7/17/2020		cBOD	CCT Effluent	4		mg/L	cBOD-CCTE-12	NYEnvironmental			<
12	7/17/2020	9:36	Enterococcus	Plant Influent	984,000		MPN/100mL	EC-PI-12	NYEnvironmental			
12	7/17/2020	8:58	Enterococcus	Primary Effluent	410,600		MPN/100mL	EC-PE-12	NYEnvironmental			
12	7/17/2020	8:30	Enterococcus	Final Tank Effluent	35,600		MPN/100mL	EC-FTE-12	NYEnvironmental			
12	7/17/2020	7:50	Enterococcus	CCT Effluent	10		MPN/100mL	EC-CCTE-12	NYEnvironmental			
12	7/17/2020	8:30	Enterococcus	Final Tank Effluent	40,650		MPN/100mL	EC-FTE-12	NYEnvironmental			
12	7/17/2020	9:36	Fecal Coliform	Plant Influent	6,530,000		MPN/100mL	FC-PI-12	NYEnvironmental			
12	7/17/2020	8:58	Fecal Coliform	Primary Effluent	324,000		MPN/100mL	FC-PE-12	NYEnvironmental	not typical of primary effluent fecal		
12	7/17/2020	8:30	Fecal Coliform	Final Tank Effluent	560,000		MPN/100mL	FC-FTE-12	NYEnvironmental			
12	7/17/2020	7:50	Fecal Coliform	CCT Effluent	72		MPN/100mL	FC-CCTE-12	NYEnvironmental			
12	7/17/2020	8:30	Fecal Coliform	Final Tank Effluent	650,000		MPN/100mL	FC-FTE-12	NYEnvironmental			
12	7/17/2020		TSS	Plant Influent	170		mg/L	TSS-PI-12	NYEnvironmental			
12	7/17/2020		TSS	Primary Effluent	46		mg/L	TSS-PE-12	NYEnvironmental			
12	7/17/2020		TSS	Final Tank Effluent	5		mg/L	TSS-FTE-12	NYEnvironmental			<
12	7/17/2020		TSS	CCT Effluent	4		mg/L	TSS-CCTE-12	NYEnvironmental			
1	6/29/2020		Cylinder Reading Average	Aeration Tank Effluent	450		mL/L	CRA-ATE-01	Plant			
2	6/30/2020		Cylinder Reading Average	Aeration Tank Effluent	313		mL/L	CRA-ATE-02	Plant			
3	7/1/2020		Cylinder Reading Average	Aeration Tank Effluent	343		mL/L	CRA-ATE-03	Plant			
4	7/7/2020		Cylinder Reading Average	Aeration Tank Effluent	170		mL/L	CRA-ATE-04	Plant			
5	7/8/2020		Cylinder Reading Average	Aeration Tank Effluent	330		mL/L	CRA-ATE-05	Plant			
6	7/9/2020		Cylinder Reading Average	Aeration Tank Effluent	223		mL/L	CRA-ATE-06	Plant			
7	7/10/2020		Cylinder Reading Average	Aeration Tank Effluent	128		mL/L	CRA-ATE-07	Plant			
8	7/13/2020		Cylinder Reading Average	Aeration Tank Effluent	85		mL/L	CRA-ATE-08	Plant			
9	7/14/2020		Cylinder Reading Average	Aeration Tank Effluent	90		mL/L	CRA-ATE-09	Plant			
10	7/15/2020		Cylinder Reading Average	Aeration Tank Effluent	98		mL/L	CRA-ATE-10	Plant			
11	7/16/2020		Cylinder Reading Average	Aeration Tank Effluent	88		mL/L	CRA-ATE-11	Plant			
12	7/17/2020		Cylinder Reading Average	Aeration Tank Effluent	60		mL/L	CRA-ATE-12	Plant			
1	6/29/2020		MLSS	Aeration Tank Effluent	1,160		mg/L	MLSS-ATE-01	Plant			
2	6/30/2020		MLSS	Aeration Tank Effluent	1,070		mg/L	MLSS-ATE-02	Plant			
3	7/1/2020		MLSS	Aeration Tank Effluent	980		mg/L	MLSS-ATE-03	Plant			
4	7/7/2020		MLSS	Aeration Tank Effluent	1,020		mg/L	MLSS-ATE-04	Plant			
5	7/8/2020		MLSS	Aeration Tank Effluent	780		mg/L	MLSS-ATE-05	Plant			
6	7/9/2020		MLSS	Aeration Tank Effluent	670		mg/L	MLSS-ATE-06	Plant			
7	7/10/2020		MLSS	Aeration Tank Effluent	560		mg/L	MLSS-ATE-07	Plant			
8	7/13/2020		MLSS	Aeration Tank Effluent	770		mg/L	MLSS-ATE-08	Plant			
9	7/14/2020		MLSS	Aeration Tank Effluent	765		mg/L	MLSS-ATE-09	Plant			
10	7/15/2020		MLSS	Aeration Tank Effluent	760		mg/L	MLSS-ATE-10	Plant			
11	7/16/2020		MLSS	Aeration Tank Effluent	770		mg/L	MLSS-ATE-11	Plant			
12	7/17/2020		MLSS	Aeration Tank Effluent	780		mg/L	MLSS-ATE-12	Plant			
1	6/29/2020		SVI	Aeration Tank Effluent	387.9310345		mL/g	SVI-ATE-01	Plant			
2	6/30/2020		SVI	Aeration Tank Effluent	292.5233645		mL/g	SVI-ATE-02	Plant			
3	7/1/2020		SVI	Aeration Tank Effluent	350		mL/g	SVI-ATE-03	Plant			
4	7/7/2020		SVI	Aeration Tank Effluent	166.6666667		mL/g	SVI-ATE-04	Plant			
5	7/8/2020		SVI	Aeration Tank Effluent	423.0769231		mL/g	SVI-ATE-05	Plant			
6	7/9/2020		SVI	Aeration Tank Effluent	332.8358209		mL/g	SVI-ATE-06	Plant			
7	7/10/2020		SVI	Aeration Tank Effluent	228.5714286		mL/g	SVI-ATE-07	Plant			
8	7/13/2020		SVI	Aeration Tank Effluent	110.3896104		mL/g	SVI-ATE-08	Plant			
9	7/14/2020		SVI	Aeration Tank Effluent	117.6470588		mL/g	SVI-ATE-09	Plant			
10	7/15/2020		SVI	Aeration Tank Effluent	128.9473684		mL/g	SVI-ATE-10	Plant			
11	7/16/2020		SVI	Aeration Tank Effluent	114.2857143		mL/g	SVI-ATE-11	Plant			
12	7/17/2020		SVI	Aeration Tank Effluent	76.92307692		mL/g	SVI-ATE-12	Plant			
1	6/29/2020	8:00	Flow	Plant Influent	22		MGD	Flow-PI-01	Plant			
2	6/30/2020	8:00	Flow	Plant Influent	20		MGD	Flow-PI-02	Plant			
3	7/1/2020	8:00	Flow	Plant Influent	21		MGD	Flow-PI-03	Plant			
4	7/7/2020	8:00	Flow	Plant Influent	31		MGD	Flow-PI-04	Plant			
5	7/8/2020	8:00	Flow	Plant Influent	21		MGD	Flow-PI-05	Plant			
6	7/9/2020	8:00	Flow	Plant Influent	20		MGD	Flow-PI-06	Plant			
7	7/10/2020	8:00	Flow	Plant Influent	20		MGD	Flow-PI-07	Plant			
8	7/13/2020	8:00	Flow	Plant Influent	25		MGD	Flow-PI-08	Plant			
9	7/14/2020	8:00	Flow	Plant Influent	19		MGD	Flow-PI-09	Plant			
10	7/15/2020	8:00	Flow	Plant Influent	18		MGD	Flow-PI-10	Plant			
11	7/16/2020	8:00	Flow	Plant Influent	19		MGD	Flow-PI-11	Plant			
12	7/17/2020	8:00	Flow	Plant Influent	26		MGD	Flow-PI-12	Plant			

Appendix B

DEP Notes and Sampling Results

CDM Smith

Table B1 - DEP Notes and Sampling Results

	Flow					10:00 AM Cylinder	TRC Target	RAS Chlor	Foaming	Rain Day	Contractor work*	MLSS	MLSS	SVI = (Cylinder Reading Avg/MLSS) x1000	Influent pH	Effluent pH	Effluent Temp	Notes
	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	Reading Avg (mL/L)	(mg/L)	Dose (mg/L)	Condition	(Yes/No)		Date	(mg/L)	(mL/g)			(°C)	
6/29/2020	27	22	22	22	22	450	0.25	8.8	Heavy	No	--	6/29/2020	1160	388	6.97	7.25	23.5	Please note we are currently experiencing come foaming issues as a result of M. Parvicella filaments. pH and Temp taken at 9:30 AM. June 29th Cylinder average is 450 mL/L unfortunately due to reduced sampling during covid we only get MLSS numbers for Mon, Wed, and Fri. I'll be able to get those numbers to you late tomorrow after they are analyzed by the Lab.
6/30/2020	18	20	22	21	22	313	0.25	8.8	Heavy	No	Yes	--	1070	293				Contractor work on June 30th and July 14th required the primary sludge pumping to be off during the sampling time period which may have affected the quality of primary effluent.
7/1/2020	21	21	21	19	24	343	0.25	8.8	Heavy	Yes	--	7/1/2020	980	350				
7/2/2020	17	18	19	18	21	350	0.25	8.8	Heavy	Yes	--	7/3/2020	800	438				
7/7/2020	23	31	20	24	29	170	0.35	6.3	Medium	No	--	7/6/2020	1020	167				
7/8/2020	19	21	21	19	22	330	0.35	6.3	Medium	No	--	7/8/2020	780	423				
7/9/2020	20	20	20	21	24	223	0.35	6.3	Light	No	--	--	670	333				
7/10/2020	23	20	20	20	21	128	0.35 to 1.0	6.3	Light	Yes	--	7/10/2020	560	229				
7/13/2020	25	25	24	24	26	85	0.45	Off	None	No	--	7/13/2020	770	110				
7/14/2020	19	19	21	21	27	90	0.45	Off	None	No	Yes	--	765	118				Contractor work on June 30th and July 14th required the primary sludge pumping to be off during the sampling time period which may have affected the quality of primary effluent.
7/15/2020	18	18	19	19	24	98	0.45	Off	None	No	--	7/15/2020	760	129				
7/16/2020	18	19	24	23	23	88	0.45	Off	None	No	--	--	770					
7/17/2020	22	26	25	25	26	60	0.45	Off	None	No	--	7/17/2020	780	77				

Appendix C
Chlorine Demand Testing

Standard Operating Procedure ETL-020

Chlorine Demand Testing

Revision 1

Joshua Registe

A. Scope and Application

For determining the chlorine demand and the chlorine requirement in drinking water production. For establishing chlorine demand constants and establishing historical background data on raw water quality. This SOP was adapted from the SM-2350, SM-4500-Cl-G, the Hach free and total chlorine methods.

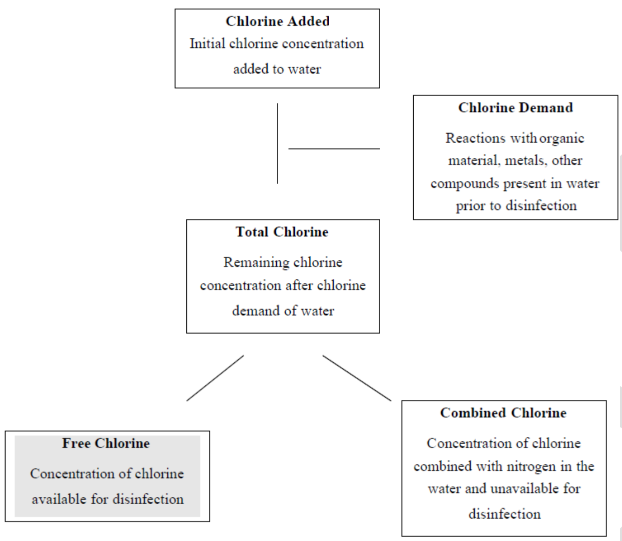


Figure 1 – Chlorine Addition Flowchart (Source: *Chlorine Residual Testing Fact Sheet, CDC SWS Project*)

B. Background

The chlorine demand of a water sample is defined as the difference between the concentration of chlorine added to the sample and the concentration of the chlorine residual remaining at the end of a predetermined contact time. The chlorine demand is a function of chlorine concentration, sample temperature, contact time and sample pH and temperature. The chlorine requirement is the amount of chlorine required to achieve a predetermined chlorine residual at a prescribed contact time, pH and temperature. Chlorine demand is caused by a complex set of reactions. Chlorine reacts with dissolved or suspended organic materials in the water to form stable chlorinated organic compounds such as trihalomethanes, haloacetic acids or other chlorinated organic compounds. Some of these compounds (trihalomethanes) are referred to as disinfection by-product (DBPs) and are regulated under the Disinfection/Disinfection By-Products Rule; other chlorinated organics contribute to taste and odor problems. As a general rule, the lower the chlorine demand the lower the amounts of DBPs formed and less taste and odor problems occur. Chlorine also is reduced by inorganic reductants present such as ferrous, manganous, nitrite, sulfide and sulfite ions. Ammonia present in the water also consumes chlorine to form chloramines.

C. SAFETY/HAZARDS

Always wear safety glasses and nitrile gloves when working with untreated waste water or the chemicals used in this SOP. Wear goggles if there is the possibility of splashing or spraying in the eye.

When sampling the wastewater and treated water, use proper PPE to avoid contact with samples and to prevent exposure bacteria and chemicals in them. If necessary, handle samples in the fume hood to reduce odors. Thoroughly clean work area and glassware with an appropriate disinfectant after use. Contact the Chemical Hygiene Officer (CHO) or laboratory management immediately if there is any chance blood borne exposure has occurred.

Hach chlorine reagent powders may cause eye irritation, respiratory tract irritation or allergic skin reaction. As long as no additional hazards are present in the sample water, sample waste can be diluted 5x and then disposed of down the drain. Refer to the sample shipment memo or contact the CHO if you have any questions.

D. EQUIPMENT AND INSTRUMENTS

- Combined pH and temperature probe and meter
- Hach DR 2800 Spectrophotometer
- Hach 10mL Sample Cuvette, PN 249540 (For low range analysis)
- Hach 25mL 1cm flat path Sample Cell, PN 5940506 (For high range analysis)
- Amber bottle
- Stir bars
- Stir plate
- Timer

Note: All glassware and stir bars used in the test should be prepared as chlorine demand free per section K below.

E. INTERFERENCES

Water used for dilutions should be free of organic or chemical reductants. Precondition glassware and stir bars used in the test to be chlorine demand free. Use good microbial laboratory practices to prevent contamination of the prepared materials. Do not handle prepared bottles without gloves. Use metal tongs or tweezers to handle prepared stir bars. Other physical and chemical interferences include: extreme sample pH, hardness, bromine, chlorine dioxide, iodine, manganese, ozone, peroxides, and monochloramine. Refer to the Hach method for details and treatments. Read samples within the prescribed period. Chlorine standards not prepared the day of use should be stored in an amber bottle. The demand test should be performed in an amber bottle to minimize light exposure.

F. Restrictions/Limitations

Chlorine demand is significantly impacted by the physical and chemical characteristics of the water sample. Chlorine demand studies ran at 10 °C will be considerably different than studies ran at 20 °C. The chlorine demand test for this study should be run at 20C ± 1. It is imperative that the sample temperature, pH and chlorine dose be accurately measured and recorded. It is difficult to extrapolate chlorine demand data from one water source to another. Demand studies need to be performed directly on the water source of interest. This provides the information required to establish chlorine demand constants, to provide usable historical data and to provide the test requirements for making repeatable and meaningful chlorine demand measurements.

G. Reagents and Chemicals

Name	Description
Chlorine Demand Free Water	ASTM1, prepared per section I below or HPLC grade water
Sodium Hypochlorite Solution, various concentrations	Clear colorless liquid with chlorine odor. Used to create a known concentration chlorine stock for dosing sample water.
Hach DPD Free Chlorine Reagent Powder Pillows, 10 or 25 mL (Catalog# 2105569 and 1407099)	White or light pink powder. Proprietary mix of Salt of N,N-Diethyl-p-Phenylenediamine, Carboxylate Salt, Sodium Phosphate Dibasic Heptahydrate, and Ethylenediaminetetraacetic Acid Disodium Salt. Hach AccuVac Ampules may be substituted if sample volumes allow.
Hach DPD Total Chlorine Reagent Powder Pillows, 10 or 25 mL (Catalog# 2105669 and 1406499)	White or light pink powder. Proprietary mix of Potassium iodide, Salt of N,N-Diethyl-p-Phenylenediamine, Carboxylate Salt, and Sodium Phosphate Dibasic. 10mL packets are used for low range analysis (0.02-2.00 mg/L). 25mL packets are used for mid (0.05 – 4.00

	mg/L) and high (0.1 – 10.0 mg/L) range analysis. Hach AccuVac Ampules may be substituted if sample volumes allow.

H. Quality Control

The acceptance criteria stated in the SOP are for the average of all QC samples over the project, unless stated otherwise in the QAPP or other project documentation. Individual samples not meeting criteria should be verified by reanalysis if possible. Samples destroyed or altered during the analytical process may not be recoverable for result verification.

As samples are time dependent, duplicate samples are not feasible. Replicate timed experiments shall be run. Sample water is used to zero the spectrophotometer. Accuracy checks may be performed using Hach Ampule standards if required for the project. The spectrophotometer is zeroed with a representative water sample free of added chlorine.

Samples should be refrigerated and shipped at 4 °C and analyzed as soon as possible. Samples can be preserved up to 28 days at -20 °C.

The solution created will be low strength in order to ensure that the dosing volume is measured easily and accurately doses. This reduces the chance of dosage error by small amounts of hypochlorite.

Dosing solution strength should be checked either using the method of standard addition and DPD test kits, or ideally by using a digital titrator from Hach.

I. Preparation of Chlorine Demand Free Water

For wastewater samples, use ASTM 1 water. Collect the quantity of ASTM 1 water required for all operations.

1. Dose an aliquot of the water to a known chlorine concentration that can be analyzed without further dilution.
2. Measure the free and total chlorine 1-3 minutes after dosing per the procedure below. Results should be within +/- 20% of each other.

J. Preparation of Chlorine Demand Free Glassware

After the normal dishwashing procedure, rinse the glassware and stir bars with copious amounts of chlorine demand-free water before filling with sample. Handle glassware/stir bars with clean gloves or stainless steel tongs only.

K. Test Procedures

Samples should be dosed with a known concentration of sodium hypochlorite solution. Typical wastewater doses are between 1 and 15 mg/L.

The dose matrix will be as follows:

1. Create standard solution of 500 mg/L chlorine.
2. Add 1L of wastewater sample to a 2L glass beaker on a stir plate.
3. Measure the sample temperature and pH.
4. Dose with a known concentration of sodium hypochlorite to achieve target dose (e.g. a target dose of 1mg/L would require 2mL of 500mg/L standard solution) to 1 L wastewater sample and and start the timer.
5. Mix rapidly upon dosing for the first 30 seconds, and gradually for the desired contact period.
6. Pull aliquots of the sample/hypochlorite mixture at the pre-determined intervals for chlorine residual analysis. Adjust dilution factors as the total chlorine drops and free chlorine increases.
7. Repeat investigation to duplicate results.

The following test matrices shall be produced:

Screening	
Starting Temperature	
Starting pH	
	5 minutes Contact Time
Chlorine Dose (mg/L)	TRC (mg/L)
0.5	
1	
1.5	
2	
3	

Investigation 1			
	Starting Temperature		
	Starting pH		
		2 min Contact Time	30 min Contact Time
Target TRC	Chlorine Dose (mg/L)	TRC (mg/L)	TRC (mg/L)
0.2	TBD		
0.4	TBD		
0.6	TBD		
0.8	TBD		
1	TBD		

Investigation 1 Duplicate			
	Starting Temperature		
	Starting pH		
		2 min Contact Time	30 min Contact Time
Target TRC	Chlorine Dose (mg/L)	TRC (mg/L)	TRC (mg/L)
0.2	TBD		
0.4	TBD		
0.6	TBD		
0.8	TBD		
1	TBD		

The screening investigation will be used to determine what doses should be applied to investigation 1 based on a target residual concentration and chlorine residual will be measure at the specified contact times. These series of investigations shall be conducted on the same day. And will be done twice throughout sampling study.

L. Total Chlorine Analysis Procedure

1. Verify the appropriate sample cell and powder pillow for the anticipated dosage range:

Chlorine Dose	Sample & Cell	Powder Pillow	Hach Program

0.02 to 2.00 mg/L Cl_2	10 mL in Hach 2495402 cell	10mL Powder Pillow	80 Chlorine, F&T PP
0.1 to 10 mg/L Cl_2	5 mL in Hach 5940506 cell	25mL Powder Pillow	88 Chlorine F&T HR
0.02 to 2.00 mg/L Free Cl_2	10 mL in Hach 2495402 cell	10mL Powder Pillow	85 Chlorine, F&T AV

2. If necessary, add demand free water for dilution to the sample cell and then sample water.
3. Enter the appropriate program on the spectrophotometer. (See above)
4. Wipe the prepared sample and zero the spectrophotometer with the sample water.
5. Add the powder pillow, swirl for 20 seconds.
6. Analyze the sample.

   6.1. For Free Chlorine: Wipe the prepared sample and analyze within 1 minute of adding the reagent.
   6.2. For Total Chlorine: Start the time and allow the sample to sit for the 3 minute reaction period. Within 3 minutes after the timer expires, wipe the prepared sample, insert it into the cell holder to read.

7. Results are given in mg/L Cl_2.

M. CALCULATIONS

Calculate the residual concentration at each sample point in mg/L Cl_2:

$$Residual\ Concentration = Dilution\ Factor\ x\ Reading$$

N. INTERPRETATION AND RESULTS

The chlorine demand (in mg/L Cl_2) is calculated as follows for each time point:

$$Demand = Dose - Residual\ Concentration$$

O. TRAINING

In order to be considered proficient at the procedures explained in this document, laboratory staff must have:

- Read and understood the content of this SOP

P. References

1. Hach Chlorine, Total, HR, Method 10070
2. Hach Chlorine, Total, LR, Method 8167
3. Standard Method 2350-Cl-B
4. Standard Method 4500-Cl-G

Document History

Revision	Approval Date	Changes	Retirement Date
1	06/10/2020	New document	

CDM Smith

Appendix D

Particle Size Distribution Report

Report of Analysis

PTL Project 48451-21

Prepared for: Joshua Registe **P.O.#:** Credit Card

Company: CDM SMITH **Sample(s) Received:** 2020-07-14 & 2020-07-16

PARTICLE SIZE AND CONCENTRATION SUMMARY

SAMPLE(S) SUBMITTED
Activated Sludge
Received 2020-07-14
XAD-ATE-08
Received 2020-07-16
XAD-ATE-10

Analytical information, results, and any further commentary are detailed on the following page(s).

Project Director: For Samantha Ponziani, Particle Characterization Chemist I — Date: 2020-07-31

Technical Review: Michael K. Vinakos, Particle Characterization Chemist IV/Team Leader — Date: 2020-07-31

H:\Reports\48451-21.docx

Activated Sludge
PARTICLE SIZE AND CONCENTRATION SUMMARY

INSTRUMENT	ACCESSORY	TECHNIQUE
A7000AD	Gravity Drain	Single Particle Optical Sensing (SPOS)
REFERENCE(S)		
PTL Test Method: N/A		
Client Method: N/A		

PARTICLE SIZE DATA SUMMARY

SAMPLE ID	CUMULATIVE NUMBER % LESS THAN INDICATED SIZE (µm)			NUMBER WEIGHTED MEAN (µm)
	10th Percentile	50th Percentile	90th Percentile	
Activated Sludge				
XAD-ATE-08 @ LDL 0.5 µm	0.53	0.60	0.81	0.75
XAD-ATE-08 @ LDL 1.5 µm	1.74	4.34	29.91	11.75
XAD-ATE-10 @ LDL 0.5 µm	0.52	0.60	0.89	0.88
XAD-ATE-10 @ LDL 1.5 µm	1.71	4.74	39.73	14.47

SAMPLE ID	CUMULATIVE VOLUME % LESS THAN INDICATED SIZE (µm)			VOLUME WEIGHTED MEAN (µm)
	10th Percentile	50th Percentile	90th Percentile	
Activated Sludge				
XAD-ATE-08 @ LDL 0.5 µm	41.12	111.05	197.22	121.39
XAD-ATE-08 @ LDL 1.5 µm	71.65	381.32	444.68	125.28
XAD-ATE-10 @ LDL 0.5 µm	40.00	106.02	188.91	111.75
XAD-ATE-10 @ LDL 1.5 µm	73.70	385.56	445.53	109.84

PARTICLE CONCENTRATION DATA SUMMARY

SAMPLE ID	STOCK CONCENTRATION NUMBER OF PARTICLES/mL ≥ 0.50 µm
Activated Sludge	
XAD-ATE-08	1.68×10^{7}
XAD-ATE-10	8.96×10^{6}

Activated Sludge
PARTICLE SIZE AND CONCENTRATION SUMMARY (Continued)

Attachment(s):

- An explanation page titled *Interpreting Your Single Particle Optical Sensing Analysis*.
- Original result page(s).

Comment(s):

The lower size limit of this analysis was set at 0.50 and 1.50 µm.

Both samples were concentrated and polydisperse with particles spanning the entire range of the instrument's effective range (0.5 µm – 400 µm). Given the level of dilution needed to analyze the samples in an appropriate concentration range for the instrument, a second analysis with a truncated lower detection limit was performed to improve the sample size for better statistics on the less frequent large particles. Some particles were observed microscopically to be above the instrument's upper limit, such that the upper end of the distribution may be subject to greater error. PTL suspects this is responsible for the uptick in counts in the last channel on both datasets with the raised lower limit. However, due to the way the instrument reports such oversize counts, these particles are not represented in the tabular channel data.

Particle Technology Labs

555 Rogers Street, Downers Grove, IL 60515
630-969-2703 ph 630-969-2745 fx
www.particletechlabs.com

THE PARTICLE EXPERTS

INTERPRETING YOUR SINGLE PARTICLE OPTICAL SENSING ANALYSIS

INTRODUCTION

Your samples have been analyzed on a Particle Sizing Systems AccuSizer 770, 780, or A7000 System, a particle counter capable of determining both particle size and concentration of suspensions. The AccuSizer utilizes Single Particle Optical Sensing (SPOS) technology (also referred to as the photozone technique) to provide excellent resolution, wide dynamic range, and high accuracy.

SPOS utilizes two physical principles of detection; light extinction (also known as light obscuration) for particles larger than approximately 1.5 µm and light scattering for particles smaller than 1.5 µm. During analysis, a dilute suspension of particles is passed through a region of uniform illumination produced by a laser diode. Particles greater than approximately 1.5 µm are detected by the amount of light they obscure to the extinction detector, while smaller particles are detected by the intensity of light scattered at a range of angles towards a separate detector. The particle size is then determined by comparing the pulse heights to a calibration curve generated with standard reference materials of known size. The data are presented on the basis of **CIRCULAR EQUIVALENT DIAMETER**. This analytical technique is summarized under ISO 21501-2:2007 *Determination of particle size distribution -- Single particle light interaction methods -- Part 2: Light scattering liquid-borne particle counter* and ISO 21501-3:2007 *Determination of particle size distribution -- Single particle light interaction methods -- Part 3: Light extinction liquid-borne particle counter.*

All AccuSizer systems consist of a pulse height analyzer, fluidics module, and sensor.

Pulse Height Analyzer	Commonly referred to as the "counter box," the pulse height analyzer converts pulses from the sensor into particle size. AccuSizer pulse height analyzers are multichannel and can report results in up to 1024 size channels, providing excellent resolution.
Fluidics Module	The fluidics module determines how sample is transported through the sensor. Multiple fluidics configurations are available at PTL: including auto-dilution, metered drain, and syringe injection. The most appropriate for your sample was selected depending on the particle concentration and other sample characteristics.
Sensor	Particles flowing through the sensor scatter and obscure laser light, creating pulses proportional to the particle size. Particles must pass the sensing zone one at a time to prevent what are known as coincidence errors. Hence, dilution in a clean, chemically compatible fluid is often required. While multiple sensor models are available for the AccuSizer, the most commonly used model at PTL is the LE400 sensor with a nominal range of 0.5 µm to 400 µm.

Since SPOS analyzers are true particle **COUNTERS**, data can be reported in two formats – NUMBER (count or frequency) and VOLUME. For your reference, the data have been reported using both of these formats. The 10th, 50th, and 90th percentiles on both the NUMBER and VOLUME basis are also summarized. These percentiles will indicate the particle size where the percentage of the distribution lies below. For example, a 90th percentile value of 10 µm indicates that 90% of the distribution lies below 10 µm.

NUMBER (COUNT or FREQUENCY) DATA

Your data will include a **NUMBER WEIGHTED DIFFERENTIAL FREQUENCY** histogram**,** which plots the percentage of particles detected *versus* the size of the particles detected, on a log scale. The particle size distribution (PSD) is constructed particle by particle meaning each particle has equal weighting. For instance, a 1 µm particle will have just as much impact on the distribution as a 100 µm particle. The number data are the primary output of the AccuSizer and are used to generate all other outputs.

Since the instrument counts individual particles and a known volume of sample is analyzed, an accurate concentration value in units of particles/mL can be generated.

VOLUME DATA

Your data will also include a **DIFFERENTIAL VOLUME PERCENTAGE** graph, which plots the volume-weighted percentage of particles detected *versus* the size of the particles detected, on a log scale. The volume data are generated by assuming each particle is spherical, converting the diameter into a spherical volume to give each particle a weighting relative to its volume. Since the volume of a particle increases proportionally to the diameter cubed (D^3), the volume data are inherently weighted towards the larger particles and better represent where the bulk or mass of the system lies. For example, a spherical 1 µm particle will have a volume of 0.52 µm^3 while a 100 µm spherical particle will have a volume of approximately 523,599 µm^3. One would have to count roughly one million, 1 µm particles in order to contribute the same volume percentage as one, 100 µm particle. The volume distribution can be considered interchangeable with a mass distribution if all the particles can be assumed to have equivalent density.

CHANNEL DATA

Channel data are also provided, which present the data within each channel or bin in a tabular format. The diameter in micrometers, the number of particles detected of that size, the cumulative number of particles, number and volume percentages, and absolute volume values can be found in this section.

For additional questions specific to your analysis results, please contact us directly.

Particle Technology Labs

User: Samantha Ponziani
Protocol: General Analysis - Summation
Run Date/Time: 07/21/202013:54
Report Date/Time: 07/21/2020, 13:58

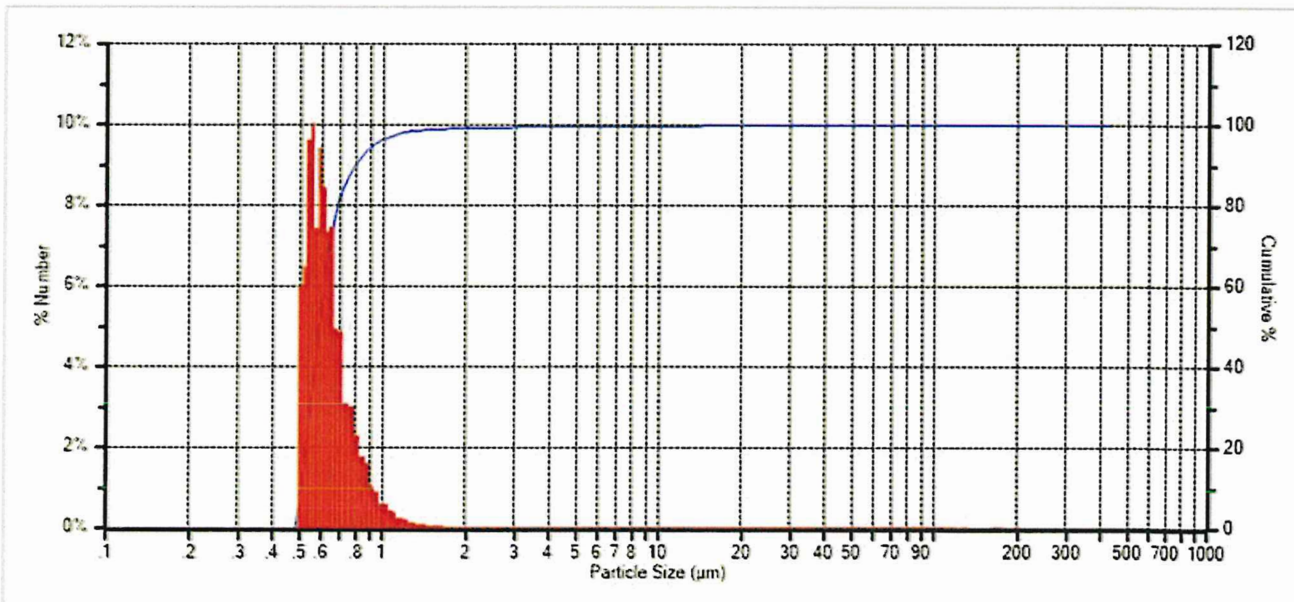
Model number: LE400
Sensor S/N: 1805909
Calibration date: 05-26-20
Sensor mode: Summation
Calibration Filename: 1805909-PTL (05-26-20)

Comment: CDM SMITH; Activated Sludge; 475188-21; 0.5um; SRP; 48451-21; Particle Technology Labs

---

Mean: 0.747 µm	Skewness: 41.3 µm	Range: 0.5 - 400 µm	Dilution Factor: 7.13
Mode: 0.554 µm	Kurtosis: 2563.8 µm	Threshold: 0.5 µm	Pre DF: 1.00
Median: 0.609 µm	Fluid Volume: 60.0 ml	Channels: 199	Background: 6.0 #/ml
Standard Deviation: 1.963 µm	Sample Time: 60 sec	Total Counts: 1679735	Counts/mL: 16797348 #/mL

XAD-ATE-08



SRP 2020-07-22
MW 2020-07-23

Particle Technology Labs

User: Samantha Ponziani
Protocol: General Analysis - Summation
Run Date/Time: 07/21/202013:54
Report Date/Time: 07/21/2020, 13:58

Model number: LE400
Sensor S/N: 1805909
Calibration date: 05-26-20
Sensor mode: Summation
Calibration Filename: 1805909-PTL (05-26-20)

Comment: CDM SMTH; Activated Sludge; 475188-21; 0.5um; SRP; 48451-21; Particle Technology Labs

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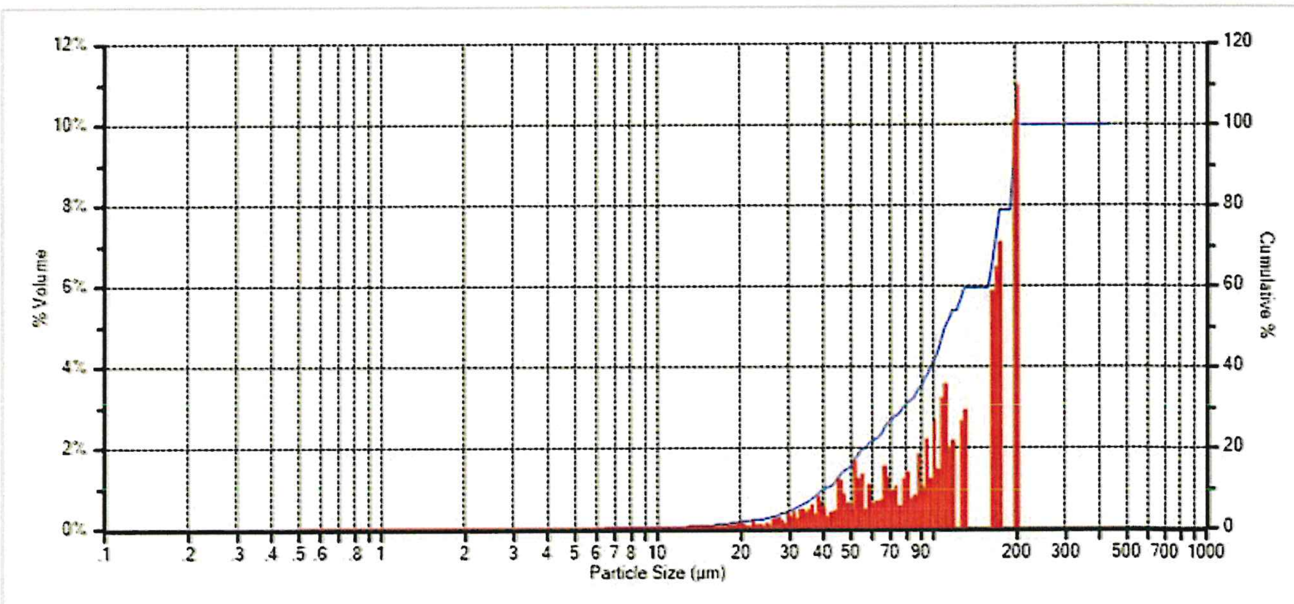
Mean: 121.385 µm	Skewness: -0.1 µm	Range: 0.5 - 400 µm	Dilution Factor: 7.13
Mode: 201.820 µm	Kurtosis: -1.4 µm	Threshold: 0.5 µm	Pre DF: 1.00
Median: 114.481 µm	Fluid Volume: 60.0 ml	Channels: 199	Background: 6.0 #/ml
Standard Deviation: 59.227 µm	Sample Time: 60 sec	Total Counts: 1679735	Counts/mL: 16797348 #/mL

XAD-ATE-08



Particle Technology Labs

Protocol: General Analysis - Summation
Project: 48451-21

Model #: LE400
Sensor S/N: 1805909
Sensor mode: Summation
Calibration file: 1805909-PTL (05-26-20)
Calibration date/time: 05-26-20
Sample Introduction: Manual
Volume sampled: 60.0 mL

Operator: SamanthaPonziani
Data collection date/time: 13:54 07/21/2020
Report Date/Time: 13:58 07/21/2020
Target concentration: 7500

Sample: XAD-ATE-08
Comment: CDM SMITH; Activated Sludge; 475188-21; 0.5um; SRP; 48451-21; Particle Technology Labs
Counts measured: 235589
Total counts (≥ 0.5 μm): 1679735
Total counts/mL (≥ 0.5 μm): 16797348 /mL
Pre DF: 1.00

Background concentration: 6.0 /mL
Summation voltage: 10.6 V
Extinction voltage: 10.7 V

	DN	DA	DV
10	0.525	1.974	41.117
50	0.600	53.264	111.051
90	0.814	171.058	197.219

Channel	Diameter (μm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (μm^3)
56	0.520	115662	222319	6.5	0.4	0.0	12.4	0.0	8524.3
57	0.537	171325	393644	9.6	0.7	0.0	22.0	0.0	13885.2
58	0.554	178698	572341	10.0	0.7	0.0	32.0	0.0	15937.1
59	0.572	132688	705030	7.4	0.6	0.0	39.5	0.0	13015.1
60	0.590	168302	873332	9.4	0.8	0.0	48.9	0.0	18141.2
61	0.609	150641	1023973	8.4	0.8	0.0	57.3	0.0	17842.1
62	0.629	131333	1155307	7.4	0.7	0.0	64.7	0.0	17126.9
63	0.651	133308	1288615	7.5	0.8	0.0	72.1	0.0	19231.9
64	0.675	87955	1376570	4.9	0.5	0.0	77.1	0.1	14136.9
65	0.702	86379	1462949	4.8	0.6	0.0	81.9	0.1	15630.9
66	0.734	54901	1517850	3.1	0.4	0.0	85.0	0.1	11370.9
67	0.771	53475	1571324	3.0	0.4	0.0	88.0	0.1	12813.3
68	0.807	41047	1612371	2.3	0.4	0.0	90.3	0.1	11304.6
69	0.843	31472	1643843	1.8	0.3	0.0	92.0	0.1	9867.4
70	0.879	28349	1672191	1.6	0.3	0.0	93.6	0.1	10080.5
71	0.916	18024	1690216	1.0	0.2	0.0	94.6	0.1	7246.9
72	0.953	16178	1706394	0.9	0.2	0.0	95.5	0.1	7324.2
73	0.989	10688	1717081	0.6	0.1	0.0	96.1	0.1	5420.7
74	1.026	10288	1727370	0.6	0.1	0.0	96.7	0.1	5818.7
75	1.063	7558	1734928	0.4	0.1	0.0	97.1	0.1	4748.8
76	1.099	7044	1741972	0.4	0.1	0.0	97.5	0.1	4901.2
77	1.136	4535	1746507	0.3	0.1	0.0	97.8	0.1	3484.6
78	1.174	4328	1750835	0.2	0.1	0.0	98.0	0.1	3666.7
79	1.212	3686	1754521	0.2	0.1	0.0	98.2	0.1	3435.3
80	1.250	2517	1757038	0.1	0.1	0.0	98.4	0.1	2575.3
81	1.289	2039	1759077	0.1	0.0	0.0	98.5	0.1	2287.7
82	1.329	1968	1761045	0.1	0.0	0.0	98.6	0.1	2416.2
83	1.369	1561	1762606	0.1	0.0	0.0	98.7	0.1	2096.0
84	1.410	1362	1763968	0.1	0.0	0.0	98.7	0.1	1997.8
85	1.452	1298	1765266	0.1	0.0	0.0	98.8	0.1	2078.9
86	1.495	1112	1766378	0.1	0.0	0.0	98.9	0.1	1945.0
87	1.539	906	1767283	0.1	0.0	0.0	98.9	0.1	1728.7
88	1.585	742	1768025	0.0	0.0	0.0	99.0	0.1	1545.8

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (µm³)
89	1.633	677	1768702	0.0	0.0	0.0	99.0	0.1	1543.1
90	1.682	656	1769358	0.0	0.0	0.0	99.0	0.1	1634.7
91	1.734	471	1769829	0.0	0.0	0.0	99.1	0.1	1284.5
92	1.789	642	1770470	0.0	0.0	0.0	99.1	0.1	1922.6
93	1.846	599	1771069	0.0	0.0	0.0	99.1	0.1	1974.0
94	1.908	478	1771547	0.0	0.0	0.0	99.2	0.1	1736.9
95	1.973	542	1772089	0.0	0.0	0.0	99.2	0.1	2180.3
96	2.043	428	1772517	0.0	0.0	0.0	99.2	0.1	1910.4
97	2.116	471	1772987	0.0	0.0	0.0	99.2	0.1	2335.9
98	2.192	364	1773351	0.0	0.0	0.0	99.3	0.1	2006.5
99	2.271	378	1773729	0.0	0.0	0.0	99.3	0.1	2318.2
100	2.353	406	1774135	0.0	0.0	0.0	99.3	0.1	2772.5
101	2.438	378	1774513	0.0	0.0	0.0	99.3	0.1	2866.7
102	2.526	307	1774820	0.0	0.0	0.0	99.4	0.1	2586.6
103	2.617	278	1775098	0.0	0.0	0.0	99.4	0.1	2610.0
104	2.712	378	1775476	0.0	0.0	0.0	99.4	0.1	3947.3
105	2.811	299	1775775	0.0	0.0	0.0	99.4	0.1	3481.2
106	2.913	299	1776075	0.0	0.0	0.0	99.4	0.1	3875.4
107	3.019	314	1776388	0.0	0.0	0.0	99.4	0.1	4520.6
108	3.129	257	1776645	0.0	0.0	0.0	99.5	0.1	4119.1
109	3.244	307	1776951	0.0	0.0	0.0	99.5	0.1	5482.0
110	3.364	264	1777215	0.0	0.0	0.0	99.5	0.1	5257.4
111	3.488	285	1777500	0.0	0.0	0.0	99.5	0.1	6336.2
112	3.617	307	1777807	0.0	0.1	0.0	99.5	0.1	7596.5
113	3.751	221	1778028	0.0	0.0	0.0	99.5	0.1	6109.9
114	3.891	299	1778328	0.0	0.1	0.0	99.5	0.1	9237.7
115	4.037	228	1778556	0.0	0.0	0.0	99.6	0.1	7857.9
116	4.188	164	1778720	0.0	0.0	0.0	99.6	0.1	6308.7
117	4.346	178	1778898	0.0	0.0	0.0	99.6	0.1	7662.7
118	4.511	228	1779126	0.0	0.1	0.0	99.6	0.1	10965.5
119	4.683	164	1779290	0.0	0.0	0.0	99.6	0.1	8815.6
120	4.862	157	1779447	0.0	0.0	0.0	99.6	0.1	9436.8
121	5.048	143	1779590	0.0	0.0	0.0	99.6	0.2	9606.0
122	5.244	185	1779775	0.0	0.1	0.0	99.6	0.2	13995.1
123	5.449	135	1779910	0.0	0.1	0.0	99.6	0.2	11475.2
124	5.664	157	1780067	0.0	0.1	0.0	99.6	0.2	14923.8
125	5.889	178	1780246	0.0	0.1	0.0	99.7	0.2	19063.8
126	6.125	164	1780410	0.0	0.1	0.0	99.7	0.2	19726.5
127	6.370	143	1780552	0.0	0.1	0.0	99.7	0.2	19300.2
128	6.626	193	1780745	0.0	0.1	0.0	99.7	0.2	29323.4
129	6.892	100	1780844	0.0	0.1	0.0	99.7	0.2	17112.5
130	7.169	107	1780951	0.0	0.1	0.0	99.7	0.2	20631.6
131	7.456	78	1781030	0.0	0.1	0.0	99.7	0.2	17018.1
132	7.752	114	1781144	0.0	0.1	0.0	99.7	0.2	27827.3
133	8.058	185	1781329	0.0	0.2	0.0	99.7	0.2	50792.8
134	8.374	135	1781465	0.0	0.1	0.0	99.7	0.3	41648.0
135	8.698	86	1781550	0.0	0.1	0.0	99.7	0.3	29474.8
136	9.029	143	1781693	0.0	0.2	0.0	99.7	0.3	54957.2
137	9.367	78	1781771	0.0	0.1	0.0	99.7	0.3	33755.1
138	9.712	71	1781843	0.0	0.1	0.0	99.7	0.3	34196.9
139	10.062	71	1781914	0.0	0.1	0.0	99.7	0.3	38027.7
140	10.421	171	1782085	0.0	0.2	0.0	99.8	0.4	101396.9
141	10.793	143	1782228	0.0	0.2	0.0	99.8	0.4	93878.5
142	11.178	50	1782278	0.0	0.1	0.0	99.8	0.4	36502.3
143	11.576	121	1782399	0.0	0.2	0.0	99.8	0.4	98439.5
144	11.984	64	1782463	0.0	0.1	0.0	99.8	0.5	57825.2
145	12.402	93	1782556	0.0	0.2	0.0	99.8	0.5	92573.6
146	12.828	100	1782655	0.0	0.2	0.0	99.8	0.5	110338.4
147	13.262	128	1782784	0.0	0.3	0.1	99.8	0.6	156728.6
148	13.699	107	1782891	0.0	0.3	0.1	99.8	0.6	143965.0
149	14.139	100	1782991	0.0	0.3	0.1	99.8	0.7	147722.8

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (% ≤ Dia.)	Volume (% ≤ Dia.)	Abs. Volume (µm³)
150	14.578	93	1783083	0.0	0.3	0.1	99.8	0.7	150341.6
151	15.012	107	1783190	0.0	0.3	0.1	99.8	0.8	189451.8
152	15.441	107	1783297	0.0	0.3	0.1	99.8	0.9	206178.4
153	15.867	64	1783361	0.0	0.2	0.0	99.8	0.9	134212.7
154	16.289	71	1783433	0.0	0.3	0.1	99.8	1.0	161360.7
155	16.711	86	1783518	0.0	0.3	0.1	99.8	1.1	209070.6
156	17.135	71	1783589	0.0	0.3	0.1	99.8	1.1	187802.3
157	17.562	64	1783654	0.0	0.3	0.1	99.8	1.2	181979.0
158	17.996	86	1783739	0.0	0.4	0.1	99.9	1.3	261090.4
159	18.442	71	1783810	0.0	0.3	0.1	99.9	1.4	234140.2
160	18.903	71	1783882	0.0	0.3	0.1	99.9	1.5	252146.6
161	19.385	86	1783967	0.0	0.4	0.1	99.9	1.6	326318.3
162	19.894	86	1784053	0.0	0.5	0.1	99.9	1.7	352716.3
163	20.433	78	1784131	0.0	0.4	0.1	99.9	1.8	350313.9
164	20.998	29	1784160	0.0	0.2	0.0	99.9	1.9	138262.3
165	21.588	36	1784196	0.0	0.2	0.1	99.9	1.9	187785.9
166	22.197	107	1784302	0.0	0.7	0.2	99.9	2.2	612437.2
167	22.823	43	1784345	0.0	0.3	0.1	99.9	2.2	266304.6
168	23.463	36	1784381	0.0	0.3	0.1	99.9	2.3	241098.1
169	24.110	29	1784409	0.0	0.2	0.1	99.9	2.4	209282.4
170	24.761	43	1784452	0.0	0.4	0.1	99.9	2.5	340052.2
171	25.421	36	1784488	0.0	0.3	0.1	99.9	2.6	306633.3
172	26.095	78	1784566	0.0	0.7	0.3	99.9	2.9	729668.0
173	26.783	71	1784638	0.0	0.7	0.3	99.9	3.1	717236.9
174	27.487	71	1784709	0.0	0.7	0.3	99.9	3.4	775275.4
175	28.206	50	1784759	0.0	0.5	0.2	99.9	3.6	586436.7
176	28.942	29	1784787	0.0	0.3	0.1	99.9	3.8	362027.0
177	29.695	78	1784866	0.0	0.9	0.4	99.9	4.1	1075324.9
178	30.466	57	1784923	0.0	0.7	0.3	99.9	4.4	844545.7
179	31.256	78	1785001	0.0	1.0	0.4	99.9	4.9	1253882.9
180	32.064	43	1785044	0.0	0.6	0.3	99.9	5.1	738423.8
181	32.894	71	1785115	0.0	1.0	0.5	99.9	5.6	1328709.9
182	33.745	64	1785179	0.0	1.0	0.5	99.9	6.1	1291104.6
183	34.619	50	1785229	0.0	0.8	0.4	99.9	6.4	1084282.0
184	35.518	57	1785286	0.0	1.0	0.5	99.9	6.9	1338201.8
185	36.443	64	1785351	0.0	1.1	0.6	99.9	7.5	1626150.9
186	37.396	36	1785386	0.0	0.7	0.3	99.9	7.8	976142.0
187	38.378	78	1785465	0.0	1.6	0.8	99.9	8.7	2321292.0
188	39.393	57	1785522	0.0	1.2	0.6	100.0	9.3	1825699.5
189	40.443	43	1785564	0.0	0.9	0.5	100.0	9.8	1481668.3
190	41.530	21	1785586	0.0	0.5	0.3	100.0	10.1	802217.1
191	42.658	29	1785614	0.0	0.7	0.4	100.0	10.5	1159189.1
192	43.831	29	1785643	0.0	0.7	0.4	100.0	11.0	1257445.0
193	45.052	71	1785714	0.0	1.9	1.2	100.0	12.2	3413781.8
194	46.327	64	1785778	0.0	1.9	1.2	100.0	13.3	3340545.2
195	47.659	43	1785821	0.0	1.3	0.9	100.0	14.2	2424760.9
196	49.055	29	1785850	0.0	0.9	0.6	100.0	14.8	1762782.8
197	50.519	21	1785871	0.0	0.7	0.5	100.0	15.3	1443975.2
198	52.045	64	1785935	0.0	2.3	1.7	100.0	17.0	4736455.3
199	53.628	43	1785978	0.0	1.7	1.2	100.0	18.2	3454793.3
200	55.272	43	1786021	0.0	1.8	1.3	100.0	19.6	3782219.8
201	56.977	14	1786035	0.0	0.6	0.5	100.0	20.1	1381025.6
202	58.745	29	1786064	0.0	1.3	1.1	100.0	21.1	3027249.6
203	60.578	14	1786078	0.0	0.7	0.6	100.0	21.7	1659837.1
204	62.480	14	1786092	0.0	0.7	0.6	100.0	22.4	1821079.0
205	64.451	14	1786106	0.0	0.8	0.7	100.0	23.1	1998933.3
206	66.494	29	1786135	0.0	1.7	1.6	100.0	24.6	4390215.9
207	68.610	21	1786156	0.0	1.4	1.3	100.0	25.9	3617232.0
208	70.803	14	1786170	0.0	1.0	0.9	100.0	26.8	2650151.6
209	73.074	14	1786185	0.0	1.0	1.0	100.0	27.9	2913389.0
210	75.425	7	1786192	0.0	0.5	0.6	100.0	28.4	1601860.7

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (μm^3)
211	77.857	14	1786206	0.0	1.2	1.2	100.0	29.7	3523833.6
212	80.374	14	1786220	0.0	1.2	1.4	100.0	31.0	3876681.8
213	82.976	7	1786228	0.0	0.7	0.8	100.0	31.8	2132746.7
214	85.665	7	1786235	0.0	0.7	0.8	100.0	32.6	2346892.8
215	88.443	14	1786249	0.0	1.5	1.8	100.0	34.4	5165353.8
216	91.310	7	1786256	0.0	0.8	1.0	100.0	35.4	2842108.7
217	94.268	14	1786270	0.0	1.7	2.2	100.0	37.7	6254796.1
218	97.319	7	1786277	0.0	0.9	1.2	100.0	38.9	3440921.0
219	100.475	14	1786292	0.0	1.9	2.7	100.0	41.5	7573464.8
220	103.762	7	1786299	0.0	1.0	1.5	100.0	43.0	4170663.9
221	107.191	14	1786313	0.0	2.2	3.2	100.0	46.3	9195778.5
222	110.763	14	1786327	0.0	2.4	3.6	100.0	49.8	10146176.1
223	114.481	7	1786334	0.0	1.3	2.0	100.0	51.8	5601299.2
224	118.346	7	1786342	0.0	1.3	2.2	100.0	54.0	6187964.8
225	122.359	0	1786342	0.0	0.0	0.0	100.0	54.0	0.0
226	126.518	7	1786349	0.0	1.5	2.7	100.0	56.7	7560393.8
227	130.824	7	1786356	0.0	1.6	3.0	100.0	59.6	8358839.3
228	135.274	0	1786356	0.0	0.0	0.0	100.0	59.6	0.0
229	139.864	0	1786356	0.0	0.0	0.0	100.0	59.6	0.0
230	144.590	0	1786356	0.0	0.0	0.0	100.0	59.6	0.0
231	149.445	0	1786356	0.0	0.0	0.0	100.0	59.6	0.0
232	154.422	0	1786356	0.0	0.0	0.0	100.0	59.6	0.0
233	159.511	0	1786356	0.0	0.0	0.0	100.0	59.6	0.0
234	164.698	7	1786363	0.0	2.6	5.9	100.0	65.5	16678104.1
235	169.969	7	1786370	0.0	2.8	6.5	100.0	72.0	18331226.3
236	175.306	7	1786377	0.0	2.9	7.1	100.0	79.1	20112902.3
237	180.688	0	1786377	0.0	0.0	0.0	100.0	79.1	0.0
238	186.091	0	1786377	0.0	0.0	0.0	100.0	79.1	0.0
239	191.484	0	1786377	0.0	0.0	0.0	100.0	79.1	0.0
240	196.832	7	1786384	0.0	3.7	10.1	100.0	89.2	28469098.9
241	201.820	7	1786392	0.0	3.9	10.8	100.0	100.0	30688495.5
242	206.025	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
243	209.445	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
244	212.355	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
245	215.087	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
246	218.043	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
247	221.698	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
248	226.615	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
249	233.454	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
250	242.984	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
251	256.098	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
252	273.824	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
253	298.486	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
254	339.043	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
255	398.611	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0
256	416.065	0	1786392	0.0	0.0	0.0	100.0	100.0	0.0

Particle Technology Labs

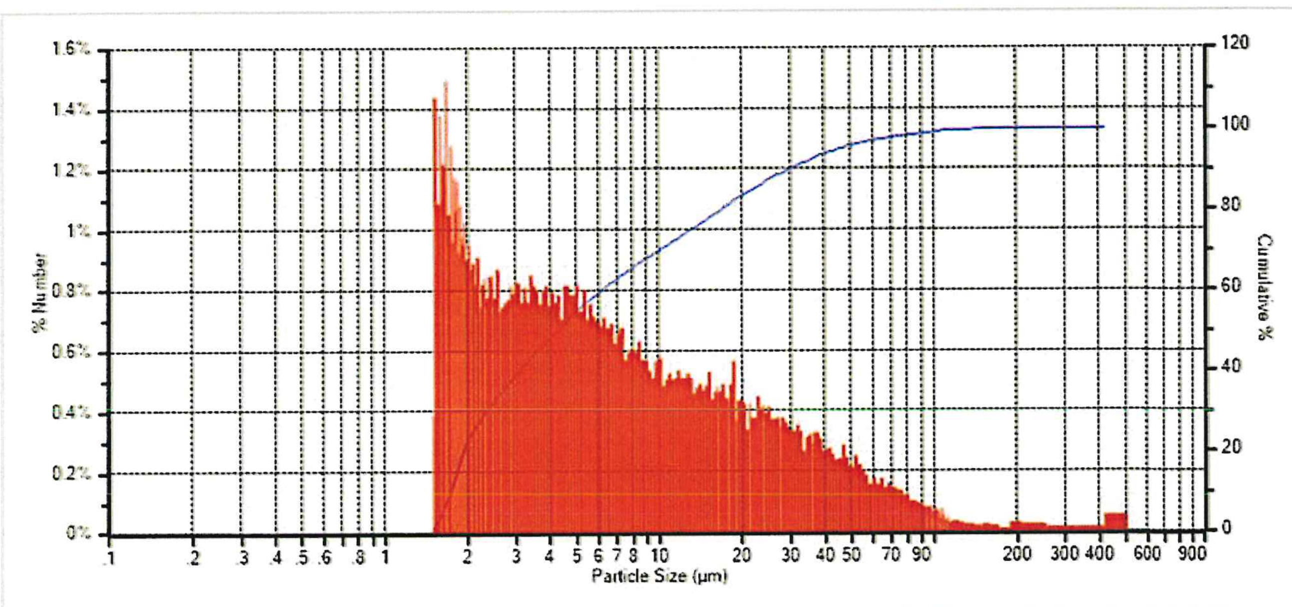
User: Samantha Ponziani
Protocol: General Analysis - Extinction
Run Date/Time: 07/21/202014:59
Report Date/Time: 07/21/2020, 15:03

Model number: LE400
Sensor S/N: 1805909
Calibration date: 05-19-20
Sensor mode: Extinction
Calibration Filename: 1805909-PTL (05-19-20)

Comment: CDM SMITH; Activated Sludge; 475188-21; 1.5um; SRP, 48451-21; Particle Technology Labs

Mean: 11.746 µm	Skewness: 4.0 µm	Range: 1.5 - 400 µm	Dilution Factor: 1.677
Mode: 1.689 µm	Kurtosis: 26.2 µm	Threshold: 1.5 µm	Pre DF: 1.00
Median: 4.408 µm	Fluid Volume: 60.0 ml	Channels: 197	Background: 0.0 #/ml
Standard Deviation: 18.435 µm	Sample Time: 60 sec	Total Counts: 189854	Counts/mL: 189854 #/mL

XAD--ATE--08



SRP 2020-07-22

MKW 2020-07-23

Particle Technology Labs

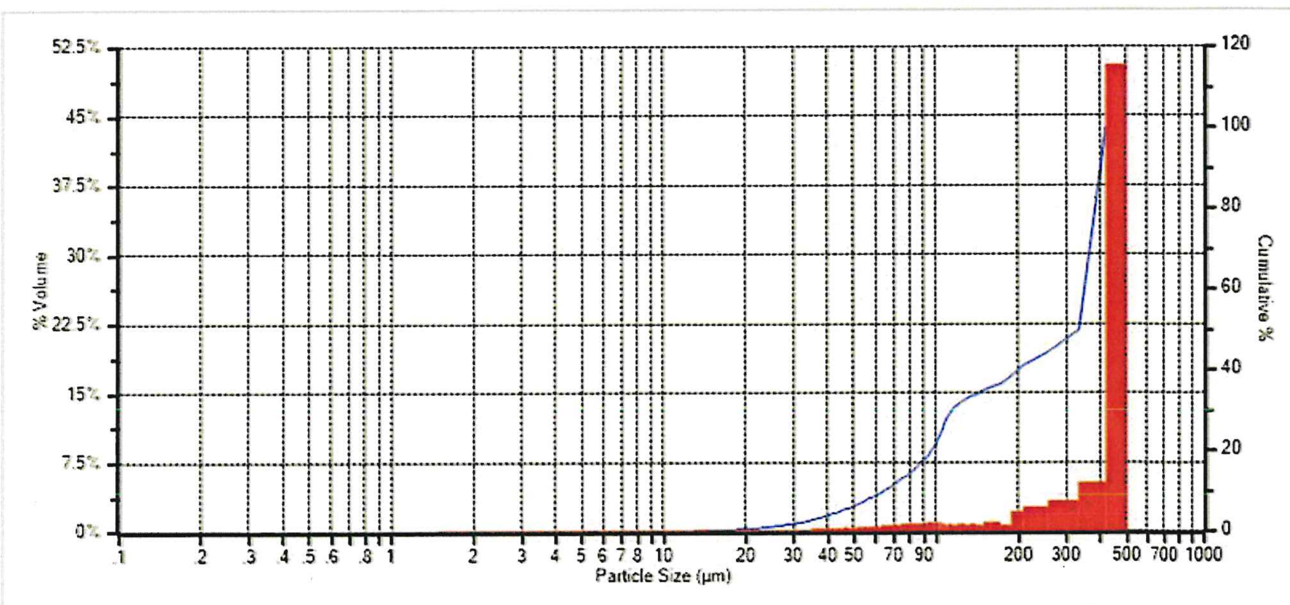
User: Samantha Ponziani
Protocol: General Analysis - Extinction
Run Date/Time: 07/21/202014:59
Report Date/Time: 07/21/2020, 15:03

Model number: LE400
Sensor S/N: 1805909
Calibration date: 05-19-20
Sensor mode: Extinction
Calibration Filename: 1805909-PTL (05-19-20)

Comment: CDM SMITH; Activated Sludge; 475188-21; 1.5um; SRP; 48451-21; Particle Technology Labs

Mean: 125.279 µm	Skewness: 1.0 µm	Range: 1.5 - 400 µm	Dilution Factor: 1.677
Mode: 293.938 µm	Kurtosis: -0.1 µm	Threshold: 1.5 µm	Pre DF: 1.00
Median: 103.516 µm	Fluid Volume: 60.0 ml	Channels: 197	Background: 0.0 #/ml
Standard Deviation: 77.115 µm	Sample Time: 60 sec	Total Counts: 189854	Counts/mL: 189854 #/mL

XAD--ATE--08



Particle Technology Labs

Protocol: General Analysis - Extinction
Project: 48451-21

Model #: LE400
Sensor S/N: 1805909
Sensor mode: Extinction
Calibration file: 1805909-PTL (05-19-20)
Calibration date/time: 05-19-20
Sample Introduction: Manual
Volume sampled: 60.0 mL

Operator: SamanthaPonziani
Data collection date/time: 14:59 07/21/2020
Report Date/Time: 15:03 07/21/2020
Target concentration: 7500

Sample: XAD--ATE--08
Comment: CDM SMITH; Activated Sludge; 475188-21; 1.5um; SRP; 48451-21; Particle Technology Labs
Counts measured: 113311
Total counts (≥ 1.5 µm): 189980
Total counts/mL (≥ 1.5 µm): 189980 /mL
Pre DF: 1.00

Background concentration: 0.0 /mL
Summation voltage: 10.6 V
Extinction voltage: 10.7 V

	DN	DA	DV
10	1.736	24.506	71.653
50	4.338	90.071	381.319
90	29.907	415.195	444.678

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (μm^3)
58	1.534	2743	3481	1.4	0.0	0.0	1.8	0.0	5181.7
59	1.567	2069	5550	1.1	0.0	0.0	2.9	0.0	4169.9
60	1.600	2626	8175	1.4	0.0	0.0	4.3	0.0	5630.1
61	1.631	2320	10496	1.2	0.0	0.0	5.5	0.0	5274.1
62	1.661	2292	12788	1.2	0.0	0.0	6.7	0.0	5497.8
63	1.689	2844	15631	1.5	0.0	0.0	8.2	0.0	7170.8
64	1.715	1999	17630	1.0	0.0	0.0	9.2	0.0	5278.9
65	1.740	2434	20064	1.3	0.0	0.0	10.5	0.0	6711.7
66	1.763	1833	21897	1.0	0.0	0.0	11.5	0.0	5256.5
67	1.785	2230	24127	1.2	0.0	0.0	12.7	0.0	6635.7
68	1.805	1942	26068	1.0	0.0	0.0	13.7	0.0	5978.9
69	1.825	2025	28094	1.1	0.0	0.0	14.7	0.0	6441.3
70	1.843	2216	30310	1.2	0.0	0.0	15.9	0.0	7270.2
71	1.862	1764	32074	0.9	0.0	0.0	16.8	0.0	5963.1
72	1.881	2056	34129	1.1	0.0	0.0	17.9	0.0	7162.6
73	1.900	1512	35642	0.8	0.0	0.0	18.7	0.0	5435.0
74	1.921	1859	37501	1.0	0.0	0.0	19.7	0.0	6904.8
75	1.944	1807	39308	0.9	0.0	0.0	20.6	0.0	6956.7
76	1.970	1955	41263	1.0	0.0	0.0	21.6	0.0	7830.5
77	2.000	1712	42975	0.9	0.0	0.0	22.5	0.0	7174.8
78	2.035	1811	44786	0.9	0.0	0.0	23.5	0.0	7987.2
79	2.072	1660	46446	0.9	0.0	0.0	24.4	0.0	7726.1
80	2.110	1698	48144	0.9	0.0	0.0	25.2	0.0	8350.3
81	2.149	1558	49702	0.8	0.0	0.0	26.1	0.0	8097.2
82	2.190	1734	51435	0.9	0.0	0.0	27.0	0.0	9535.6
83	2.232	1415	52851	0.7	0.0	0.0	27.7	0.0	8243.3
84	2.276	1556	54406	0.8	0.0	0.0	28.5	0.0	9611.1
85	2.322	1598	56004	0.8	0.0	0.0	29.4	0.0	10474.9
86	2.369	1469	57473	0.8	0.0	0.0	30.1	0.0	10226.9
87	2.418	1611	59084	0.8	0.0	0.0	31.0	0.0	11929.1
88	2.469	1618	60702	0.8	0.0	0.0	31.8	0.0	12747.5
89	2.521	1472	62174	0.8	0.0	0.0	32.6	0.0	12354.3
90	2.576	1658	63832	0.9	0.0	0.0	33.5	0.0	14836.4

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (μm^3)
91	2.632	1385	65217	0.7	0.0	0.0	34.2	0.0	13221.4
92	2.690	1413	66631	0.7	0.0	0.0	34.9	0.0	14412.9
93	2.751	1445	68076	0.8	0.0	0.0	35.7	0.0	15755.1
94	2.814	1464	69540	0.8	0.0	0.0	36.5	0.0	17073.2
95	2.879	1546	71086	0.8	0.0	0.0	37.3	0.0	19310.1
96	2.946	1506	72591	0.8	0.0	0.0	38.1	0.0	20156.8
97	3.016	1559	74150	0.8	0.0	0.0	38.9	0.0	22394.4
98	3.088	1566	75716	0.8	0.0	0.0	39.7	0.0	24146.0
99	3.163	1445	77162	0.8	0.0	0.0	40.5	0.0	23944.2
100	3.240	1537	78699	0.8	0.0	0.0	41.3	0.0	27392.4
101	3.321	1449	80148	0.8	0.0	0.0	42.0	0.0	27773.0
102	3.404	1621	81769	0.9	0.0	0.0	42.9	0.0	33472.2
103	3.490	1549	83318	0.8	0.0	0.0	43.7	0.0	34470.5
104	3.579	1519	84837	0.8	0.0	0.0	44.5	0.0	36454.3
105	3.671	1430	86267	0.7	0.0	0.0	45.2	0.0	37038.1
106	3.766	1526	87793	0.8	0.0	0.0	46.0	0.0	42669.3
107	3.864	1546	89339	0.8	0.0	0.0	46.8	0.0	46712.3
108	3.966	1422	90761	0.7	0.0	0.0	47.6	0.0	46444.3
109	4.071	1507	92268	0.8	0.0	0.0	48.4	0.0	53264.6
110	4.180	1442	93710	0.8	0.0	0.0	49.1	0.0	55148.0
111	4.292	1491	95200	0.8	0.0	0.0	49.9	0.0	61723.3
112	4.408	1338	96538	0.7	0.0	0.0	50.6	0.0	60016.4
113	4.528	1554	98093	0.8	0.0	0.0	51.4	0.0	75547.3
114	4.651	1548	99640	0.8	0.0	0.0	52.2	0.0	81529.6
115	4.778	1492	101132	0.8	0.0	0.0	53.0	0.0	85233.5
116	4.909	1492	102624	0.8	0.0	0.0	53.8	0.0	92434.1
117	5.044	1559	104184	0.8	0.0	0.0	54.6	0.0	104772.3
118	5.184	1388	105572	0.7	0.0	0.0	55.4	0.0	101244.6
119	5.329	1524	107096	0.8	0.0	0.0	56.2	0.0	120744.5
120	5.479	1335	108431	0.7	0.0	0.0	56.9	0.0	114962.5
121	5.636	1430	109861	0.7	0.0	0.0	57.6	0.0	134046.4
122	5.798	1360	111221	0.7	0.0	0.0	58.3	0.0	138769.2
123	5.966	1325	112545	0.7	0.0	0.0	59.0	0.0	147291.7
124	6.141	1289	113834	0.7	0.0	0.0	59.7	0.0	156329.8
125	6.322	1346	115181	0.7	0.0	0.0	60.4	0.0	178094.2
126	6.509	1278	116458	0.7	0.0	0.0	61.1	0.0	184458.2
127	6.702	1309	117768	0.7	0.1	0.0	61.7	0.0	206423.5
128	6.902	1184	118951	0.6	0.0	0.0	62.4	0.0	203810.7
129	7.109	1247	120199	0.7	0.1	0.0	63.0	0.0	234648.1
130	7.322	1283	121481	0.7	0.1	0.0	63.7	0.0	263627.5
131	7.542	1076	122558	0.6	0.1	0.0	64.3	0.0	241749.5
132	7.768	1130	123688	0.6	0.1	0.0	64.9	0.0	277322.1
133	8.000	1145	124833	0.6	0.1	0.0	65.5	0.0	307026.9
134	8.239	1130	125963	0.6	0.1	0.0	66.0	0.0	330922.2
135	8.484	1195	127159	0.6	0.1	0.0	66.7	0.1	382193.7
136	8.734	1081	128240	0.6	0.1	0.0	67.2	0.1	377254.9
137	8.990	1070	129310	0.6	0.1	0.0	67.8	0.1	406917.1
138	9.251	1011	130321	0.5	0.1	0.0	68.3	0.1	419049.4
139	9.516	969	131290	0.5	0.1	0.0	68.8	0.1	437229.9
140	9.785	1073	132363	0.6	0.1	0.0	69.4	0.1	526383.4
141	10.058	1091	133454	0.6	0.1	0.0	70.0	0.1	581462.6
142	10.336	915	134370	0.5	0.1	0.0	70.5	0.1	529275.8
143	10.621	952	135322	0.5	0.1	0.0	71.0	0.1	597462.9
144	10.914	993	136315	0.5	0.1	0.0	71.5	0.1	675561.5
145	11.213	954	137269	0.5	0.1	0.0	72.0	0.1	704241.9
146	11.520	969	138238	0.5	0.1	0.0	72.5	0.1	775676.6
147	11.833	1008	139245	0.5	0.1	0.0	73.0	0.1	874215.3
148	12.153	967	140213	0.5	0.1	0.0	73.5	0.1	909278.7
149	12.480	966	141178	0.5	0.1	0.0	74.0	0.1	982886.1
150	12.813	993	142171	0.5	0.1	0.0	74.5	0.2	1093216.0
151	13.152	964	143135	0.5	0.1	0.0	75.1	0.2	1148271.8

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (μm^3)
152	13.496	868	144004	0.5	0.1	0.0	75.5	0.2	1117782.6
153	13.845	907	144911	0.5	0.2	0.0	76.0	0.2	1260332.5
154	14.198	925	145836	0.5	0.2	0.0	76.5	0.2	1386897.6
155	14.555	887	146723	0.5	0.2	0.0	76.9	0.2	1431861.5
156	14.914	920	147644	0.5	0.2	0.0	77.4	0.2	1598882.1
157	15.276	999	148643	0.5	0.2	0.0	77.9	0.3	1865002.5
158	15.639	832	149474	0.4	0.2	0.0	78.4	0.3	1665363.9
159	16.004	882	150356	0.5	0.2	0.0	78.8	0.3	1892674.2
160	16.371	902	151258	0.5	0.2	0.0	79.3	0.3	2072285.6
161	16.742	875	152134	0.5	0.2	0.0	79.8	0.3	2150304.6
162	17.116	929	153062	0.5	0.2	0.0	80.3	0.4	2438773.5
163	17.496	842	153904	0.4	0.2	0.0	80.7	0.4	2360166.7
164	17.882	827	154731	0.4	0.2	0.0	81.1	0.4	2474613.3
165	18.275	925	155656	0.5	0.3	0.0	81.6	0.4	2957823.4
166	18.678	1066	156722	0.6	0.3	0.0	82.2	0.5	3638450.9
167	19.093	699	157422	0.4	0.2	0.0	82.5	0.5	2547978.8
168	19.522	820	158241	0.4	0.3	0.0	83.0	0.5	3193710.7
169	19.967	828	159070	0.4	0.3	0.0	83.4	0.6	3452196.9
170	20.427	800	159869	0.4	0.3	0.0	83.8	0.6	3569317.4
171	20.899	635	160505	0.3	0.2	0.0	84.2	0.6	3037172.9
172	21.382	803	161308	0.4	0.3	0.0	84.6	0.7	4110913.1
173	21.877	719	162027	0.4	0.3	0.0	85.0	0.7	3943255.5
174	22.384	719	162747	0.4	0.3	0.0	85.3	0.8	4223763.8
175	22.904	852	163598	0.4	0.4	0.1	85.8	0.8	5358261.8
176	23.438	773	164371	0.4	0.4	0.1	86.2	0.9	5210546.4
177	23.987	790	165161	0.4	0.4	0.1	86.6	0.9	5706407.6
178	24.551	741	165902	0.4	0.4	0.1	87.0	1.0	5742319.6
179	25.133	778	166680	0.4	0.4	0.1	87.4	1.1	6466440.6
180	25.730	701	167381	0.4	0.4	0.1	87.8	1.1	6250675.6
181	26.344	704	168085	0.4	0.4	0.1	88.1	1.2	6740930.8
182	26.975	719	168804	0.4	0.5	0.1	88.5	1.3	7392082.1
183	27.623	657	169461	0.3	0.4	0.1	88.9	1.3	7253550.9
184	28.290	719	170181	0.4	0.5	0.1	89.2	1.4	8526883.7
185	28.975	682	170863	0.4	0.5	0.1	89.6	1.5	8691909.9
186	29.680	659	171522	0.3	0.5	0.1	89.9	1.6	9020396.8
187	30.405	630	172152	0.3	0.5	0.1	90.3	1.7	9277991.1
188	31.150	629	172781	0.3	0.5	0.1	90.6	1.8	9950656.9
189	31.917	669	173450	0.4	0.6	0.1	90.9	1.9	11388792.5
190	32.706	627	174077	0.3	0.6	0.1	91.3	2.0	11486785.1
191	33.518	508	174585	0.3	0.5	0.1	91.5	2.1	10016718.5
192	34.354	592	175177	0.3	0.6	0.1	91.9	2.3	12564786.9
193	35.215	605	175782	0.3	0.6	0.1	92.2	2.4	13839944.4
194	36.102	550	176332	0.3	0.6	0.1	92.5	2.6	13548796.0
195	37.016	620	176953	0.3	0.7	0.2	92.8	2.7	16473743.5
196	37.958	619	177571	0.3	0.8	0.2	93.1	2.9	17715582.5
197	38.929	580	178151	0.3	0.8	0.2	93.4	3.1	17919365.8
198	39.931	500	178651	0.3	0.7	0.2	93.7	3.3	16655991.4
199	40.965	516	179167	0.3	0.7	0.2	93.9	3.4	18587345.2
200	42.033	520	179687	0.3	0.8	0.2	94.2	3.7	20209569.0
201	43.136	483	180170	0.3	0.8	0.2	94.5	3.9	20292933.6
202	44.276	448	180618	0.2	0.8	0.2	94.7	4.1	20345314.1
203	45.456	453	181070	0.2	0.8	0.2	94.9	4.3	22262825.3
204	46.678	543	181614	0.3	1.0	0.3	95.2	4.6	28927032.3
205	47.943	461	182075	0.2	0.9	0.3	95.5	4.9	26603296.6
206	49.254	412	182487	0.2	0.9	0.3	95.7	5.1	25804825.2
207	50.620	396	182883	0.2	0.9	0.3	95.9	5.4	26872308.5
208	52.056	473	183356	0.2	1.1	0.4	96.1	5.8	34922530.1
209	53.576	417	183773	0.2	1.0	0.3	96.4	6.1	33616536.2
210	55.181	376	184149	0.2	1.0	0.3	96.6	6.4	33040518.3
211	56.870	352	184501	0.2	1.0	0.3	96.7	6.8	33907969.9
212	58.643	292	184793	0.2	0.9	0.3	96.9	7.1	30806420.4

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (µm^3)
213	60.500	327	185119	0.2	1.0	0.4	97.1	7.5	37909120.8
214	62.439	288	185408	0.2	1.0	0.4	97.2	7.9	36756881.4
215	64.458	327	185735	0.2	1.2	0.5	97.4	8.3	45845647.8
216	66.552	270	186005	0.1	1.0	0.4	97.5	8.8	41662976.2
217	68.718	305	186310	0.2	1.2	0.5	97.7	9.3	51846697.8
218	70.950	275	186585	0.1	1.2	0.5	97.8	9.8	51419862.1
219	73.239	262	186846	0.1	1.2	0.6	98.0	10.4	53801562.4
220	75.578	255	187101	0.1	1.3	0.6	98.1	11.0	57606463.2
221	77.956	226	187328	0.1	1.2	0.6	98.2	11.5	56144838.4
222	80.358	228	187556	0.1	1.3	0.6	98.3	12.2	61953045.0
223	82.771	184	187740	0.1	1.1	0.6	98.4	12.7	54758936.3
224	85.175	188	187928	0.1	1.2	0.6	98.5	13.4	60755595.2
225	87.550	176	188104	0.1	1.2	0.6	98.6	14.0	61857295.0
226	89.871	171	188275	0.1	1.2	0.7	98.7	14.7	64997177.7
227	92.110	144	188419	0.1	1.1	0.6	98.8	15.3	59000378.5
228	94.234	156	188575	0.1	1.2	0.7	98.9	16.0	68319839.0
229	96.207	148	188723	0.1	1.2	0.7	99.0	16.7	68791275.6
230	97.985	156	188878	0.1	1.3	0.8	99.0	17.5	76807155.4
231	99.568	121	188999	0.1	1.0	0.6	99.1	18.1	62391980.4
232	100.997	131	189130	0.1	1.2	0.7	99.2	18.8	70542645.3
233	102.305	137	189267	0.1	1.2	0.8	99.2	19.6	77078575.5
234	103.516	104	189371	0.1	1.0	0.6	99.3	20.2	60374100.6
235	104.662	116	189487	0.1	1.1	0.7	99.4	20.9	69446868.4
236	105.780	86	189573	0.0	0.8	0.5	99.4	21.5	52992773.0
237	106.915	139	189712	0.1	1.4	0.9	99.5	22.4	89049621.4
238	108.122	99	189811	0.1	1.0	0.7	99.5	23.1	65467655.9
239	109.464	70	189881	0.0	0.7	0.5	99.6	23.6	48361089.7
240	111.017	67	189948	0.0	0.7	0.5	99.6	24.1	48046428.3
241	112.869	80	190029	0.0	0.9	0.6	99.6	24.7	60589862.3
242	115.123	52	190081	0.0	0.6	0.4	99.7	25.1	41522098.5
243	117.897	60	190141	0.0	0.7	0.5	99.7	25.6	51789293.1
244	121.327	65	190206	0.0	0.8	0.6	99.7	26.3	61146614.6
245	125.571	57	190263	0.0	0.8	0.6	99.8	26.9	59099267.1
246	130.808	42	190305	0.0	0.6	0.5	99.8	27.4	49122117.4
247	137.242	47	190352	0.0	0.8	0.7	99.8	28.0	63541381.7
248	145.107	30	190382	0.0	0.5	0.5	99.8	28.5	48280550.8
249	154.666	40	190423	0.0	0.8	0.8	99.8	29.3	77952937.0
250	166.219	32	190454	0.0	0.8	0.8	99.9	30.1	76600765.7
251	180.105	18	190473	0.0	0.5	0.6	99.9	30.7	56416394.5
252	197.823	49	190522	0.0	1.6	2.0	99.9	32.7	197088619.9
253	232.370	42	190563	0.0	2.0	2.8	99.9	35.5	275368611.9
254	293.938	29	190592	0.0	2.1	3.9	99.9	39.4	379008920.8
255	374.243	22	190614	0.0	2.6	6.1	99.9	45.5	598187761.6
256	408.690	0	190592	0.0	0.0	0.0	99.9	39.4	0.0

Particle Technology Labs

User: Samantha Ponziani
Protocol: General Analysis - Summation
Run Date/Time: 07/21/202015:36
Report Date/Time: 07/21/2020, 15:39

Model number: LE400
Sensor S/N: 1805909
Calibration date: 05-26-20
Sensor mode: Summation
Calibration Filename: 1805909-PTL (05-26-20)

Comment: CDM SMITH; Activated Sludge; 475230-49; 0.5um; SRP; 48451-21; Particle Technology Labs

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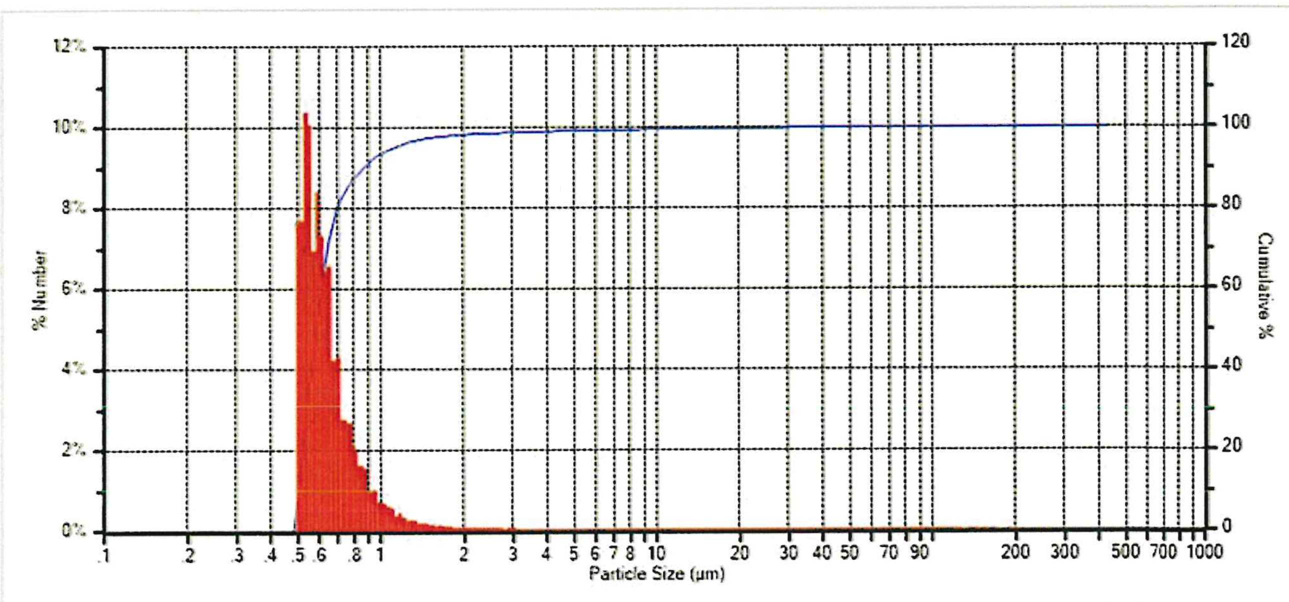
Mean: 0.881 µm
Mode: 0.537 µm
Median: 0.609 µm
Standard Deviation: 2.919 µm

Skewness: 26.4 µm
Kurtosis: 1009.0 µm
Fluid Volume: 60.0 ml
Sample Time: 60 sec

Range: 0.5 - 400 µm
Threshold: 0.5 µm
Channels: 199
Total Counts: 896164

Dilution Factor: 3.735
Pre DF: 1.00
Background: 6.0 #/ml
Counts/mL: 8961636 #/mL

XAD-ATE-10



SRP 2020-07-22

MLW 2020-07-23

Particle Technology Labs

User: Samantha Ponziani
Protocol: General Analysis - Summation
Run Date/Time: 07/21/202015:36
Report Date/Time: 07/21/2020, 15:40

Model number: LE400
Sensor S/N: 1805909
Calibration date: 05-26-20
Sensor mode: Summation
Calibration Filename: 1805909-PTL (05-26-20)

Comment: CDM SMITH; Activated Sludge; 475230-49; 0.5um; SRP; 48451-21; Particle Technology Labs

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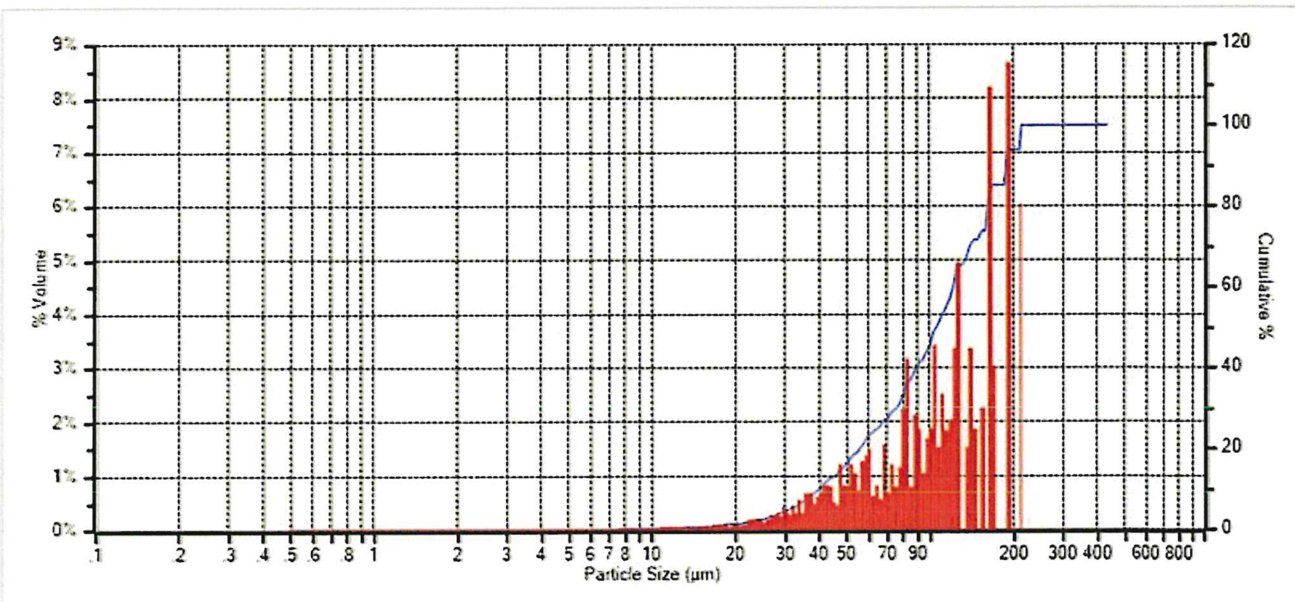
Mean: 111.748 µm	Skewness: 0.2 µm	Range: 0.5 - 400 µm	Dilution Factor: 3.735
Mode: 191.484 µm	Kurtosis: -1.0 µm	Threshold: 0.5 µm	Pre DF: 1.00
Median: 107.191 µm	Fluid Volume: 60.0 ml	Channels: 199	Background: 6.0 #/ml
Standard Deviation: 54.565 µm	Sample Time: 60 sec	Total Counts: 896164	Counts/mL: 8961636 #/mL

XAD-ATE-10



Particle Technology Labs

Protocol: General Analysis - Summation
Project: 48451-21

Model #: LE400
Sensor S/N: 1805909
Sensor mode: Summation
Calibration file: 1805909-PTL (05-26-20)
Calibration date/time: 05-26-20
Sample Introduction: Manual
Volume sampled: 60.0 mL

Operator: SamanthaPonziani
Data collection date/time: 15:36 07/21/2020
Report Date/Time: 15:38 07/21/2020
Target concentration: 7500

Sample: XAD-ATE-10
Comment: CDM SMITH; Activated Sludge; 475230-49; 0.5um; SRP; 48451-21; Particle Technology Labs
Counts measured: 239914
Total counts (≥ 0.5 μm): 896164
Total counts/mL (≥ 0.5 μm): 8961636 /mL
Pre DF: 1.00

Background concentration: 6.0 /mL
Summation voltage: 10.6 V
Extinction voltage: 10.7 V

	DN	DA	DV
10	0.523	13.772	40.001
50	0.598	57.526	106.017
90	0.894	159.869	188.908

Channel	Diameter (μm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (μm^3)
56	0.520	74509	148548	7.7	0.2	0.0	15.3	0.0	5491.4
57	0.537	100418	248965	10.4	0.3	0.0	25.7	0.0	8138.4
58	0.554	97564	346529	10.1	0.4	0.0	35.7	0.0	8701.2
59	0.572	67277	413806	6.9	0.3	0.0	42.7	0.0	6599.1
60	0.590	81281	495087	8.4	0.3	0.0	51.0	0.0	8761.3
61	0.609	70848	565936	7.3	0.3	0.0	58.3	0.0	8391.4
62	0.629	62485	628421	6.4	0.3	0.0	64.8	0.0	8148.5
63	0.651	63456	691877	6.5	0.3	0.0	71.3	0.0	9154.6
64	0.675	40895	732772	4.2	0.2	0.0	75.5	0.0	6572.9
65	0.702	41642	774413	4.3	0.2	0.0	79.8	0.0	7535.3
66	0.734	26428	800841	2.7	0.2	0.0	82.5	0.0	5473.6
67	0.771	25916	826757	2.7	0.2	0.0	85.2	0.0	6209.8
68	0.807	19558	846315	2.0	0.2	0.0	87.2	0.0	5386.5
69	0.843	15580	861895	1.6	0.1	0.0	88.8	0.0	4884.9
70	0.879	14751	876646	1.5	0.1	0.0	90.4	0.0	5245.3
71	0.916	9480	886127	1.0	0.1	0.0	91.3	0.0	3811.7
72	0.953	9876	896003	1.0	0.1	0.0	92.4	0.0	4471.3
73	0.989	6645	902648	0.7	0.1	0.0	93.0	0.0	3370.4
74	1.026	6541	909189	0.7	0.1	0.0	93.7	0.0	3699.1
75	1.063	5794	914982	0.6	0.1	0.0	94.3	0.0	3640.3
76	1.099	5229	920212	0.5	0.1	0.0	94.8	0.0	3638.5
77	1.136	3661	923872	0.4	0.1	0.0	95.2	0.0	2813.0
78	1.174	4131	928004	0.4	0.1	0.0	95.7	0.0	3500.2
79	1.212	3145	931149	0.3	0.1	0.0	96.0	0.0	2931.1
80	1.250	2548	933696	0.3	0.0	0.0	96.2	0.0	2606.7
81	1.289	2305	936001	0.2	0.0	0.0	96.5	0.0	2585.6
82	1.329	2279	938280	0.2	0.0	0.0	96.7	0.0	2797.7
83	1.369	1785	940065	0.2	0.0	0.0	96.9	0.0	2396.8
84	1.410	1602	941668	0.2	0.0	0.0	97.1	0.0	2350.8
85	1.452	1644	943311	0.2	0.0	0.0	97.2	0.0	2633.0
86	1.495	1192	944503	0.1	0.0	0.0	97.4	0.0	2083.7
87	1.539	1285	945788	0.1	0.0	0.0	97.5	0.1	2453.1
88	1.585	1076	946864	0.1	0.0	0.0	97.6	0.1	2242.7

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (µm³)
89	1.633	1136	947999	0.1	0.0	0.0	97.7	0.1	2586.9
90	1.682	953	948952	0.1	0.0	0.0	97.8	0.1	2373.7
91	1.734	826	949777	0.1	0.0	0.0	97.9	0.1	2253.4
92	1.789	900	950677	0.1	0.0	0.0	98.0	0.1	2697.2
93	1.846	654	951331	0.1	0.0	0.0	98.1	0.1	2154.5
94	1.908	635	951966	0.1	0.0	0.0	98.1	0.1	2308.8
95	1.973	642	952608	0.1	0.0	0.0	98.2	0.1	2585.1
96	2.043	572	953180	0.1	0.0	0.0	98.2	0.1	2552.2
97	2.116	613	953793	0.1	0.0	0.0	98.3	0.1	3040.9
98	2.192	568	954360	0.1	0.0	0.0	98.4	0.1	3133.0
99	2.271	564	954924	0.1	0.0	0.0	98.4	0.1	3460.2
100	2.353	463	955388	0.0	0.0	0.0	98.5	0.1	3159.9
101	2.438	445	955832	0.0	0.0	0.0	98.5	0.1	3372.1
102	2.526	370	956202	0.0	0.0	0.0	98.6	0.1	3119.9
103	2.617	489	956691	0.1	0.0	0.0	98.6	0.1	4593.0
104	2.712	430	957121	0.0	0.0	0.0	98.7	0.1	4487.1
105	2.811	359	957479	0.0	0.0	0.0	98.7	0.1	4168.6
106	2.913	396	957875	0.0	0.0	0.0	98.7	0.1	5124.1
107	3.019	388	958264	0.0	0.0	0.0	98.8	0.1	5597.9
108	3.129	243	958507	0.0	0.0	0.0	98.8	0.1	3896.3
109	3.244	336	958843	0.0	0.0	0.0	98.8	0.1	6011.2
110	3.364	310	959153	0.0	0.0	0.0	98.9	0.1	6178.7
111	3.488	280	959433	0.0	0.0	0.0	98.9	0.1	6224.1
112	3.617	303	959736	0.0	0.0	0.0	98.9	0.1	7496.8
113	3.751	265	960001	0.0	0.0	0.0	98.9	0.1	7331.2
114	3.891	273	960273	0.0	0.0	0.0	99.0	0.1	8411.7
115	4.037	276	960550	0.0	0.1	0.0	99.0	0.1	9519.9
116	4.188	232	960781	0.0	0.0	0.0	99.0	0.1	8909.4
117	4.346	303	961084	0.0	0.1	0.0	99.1	0.1	13006.9
118	4.511	217	961301	0.0	0.1	0.0	99.1	0.1	10412.4
119	4.683	280	961581	0.0	0.1	0.0	99.1	0.1	15060.3
120	4.862	205	961786	0.0	0.1	0.0	99.1	0.1	12359.8
121	5.048	228	962014	0.0	0.1	0.0	99.2	0.1	15349.3
122	5.244	217	962231	0.0	0.1	0.0	99.2	0.1	16356.0
123	5.449	217	962447	0.0	0.1	0.0	99.2	0.1	18351.9
124	5.664	161	962608	0.0	0.1	0.0	99.2	0.1	15281.6
125	5.889	179	962787	0.0	0.1	0.0	99.2	0.1	19175.9
126	6.125	213	963000	0.0	0.1	0.0	99.3	0.1	25612.0
127	6.370	239	963239	0.0	0.1	0.0	99.3	0.2	32356.3
128	6.626	131	963370	0.0	0.1	0.0	99.3	0.2	19914.3
129	6.892	161	963531	0.0	0.1	0.0	99.3	0.2	27536.0
130	7.169	179	963710	0.0	0.1	0.0	99.3	0.2	34588.3
131	7.456	153	963863	0.0	0.1	0.0	99.3	0.2	33231.4
132	7.752	179	964042	0.0	0.1	0.0	99.4	0.2	43735.9
133	8.058	164	964207	0.0	0.1	0.0	99.4	0.2	45032.7
134	8.374	194	964401	0.0	0.2	0.0	99.4	0.2	59715.9
135	8.698	153	964554	0.0	0.1	0.0	99.4	0.3	52759.3
136	9.029	172	964726	0.0	0.2	0.0	99.4	0.3	66221.5
137	9.367	131	964857	0.0	0.1	0.0	99.4	0.3	56267.9
138	9.712	108	964965	0.0	0.1	0.0	99.5	0.3	51955.3
139	10.062	112	965077	0.0	0.1	0.0	99.5	0.3	59767.8
140	10.421	134	965212	0.0	0.2	0.0	99.5	0.3	79682.3
141	10.793	176	965387	0.0	0.2	0.0	99.5	0.4	115579.3
142	11.178	131	965518	0.0	0.2	0.0	99.5	0.4	95617.3
143	11.576	131	965649	0.0	0.2	0.0	99.5	0.4	106178.0
144	11.984	108	965757	0.0	0.2	0.0	99.5	0.5	97615.4
145	12.402	116	965873	0.0	0.2	0.0	99.6	0.5	115651.6
146	12.828	116	965989	0.0	0.2	0.0	99.6	0.6	127998.9
147	13.262	67	966056	0.0	0.1	0.0	99.6	0.6	82109.6
148	13.699	93	966149	0.0	0.2	0.0	99.6	0.6	125704.7
149	14.139	112	966261	0.0	0.3	0.1	99.6	0.7	165839.0

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (μm^3)
150	14.578	93	966355	0.0	0.2	0.0	99.6	0.7	151468.3
151	15.012	78	966433	0.0	0.2	0.0	99.6	0.8	138954.6
152	15.441	60	966493	0.0	0.2	0.0	99.6	0.8	115217.4
153	15.867	90	966582	0.0	0.3	0.1	99.6	0.9	187503.0
154	16.289	75	966657	0.0	0.2	0.1	99.6	0.9	169072.8
155	16.711	86	966743	0.0	0.3	0.1	99.6	1.0	209935.3
156	17.135	90	966833	0.0	0.3	0.1	99.7	1.1	236133.8
157	17.562	120	966952	0.0	0.4	0.1	99.7	1.2	338980.6
158	17.996	78	967031	0.0	0.3	0.1	99.7	1.2	239372.9
159	18.442	90	967120	0.0	0.4	0.1	99.7	1.3	294396.9
160	18.903	45	967165	0.0	0.2	0.0	99.7	1.4	158518.6
161	19.385	60	967225	0.0	0.3	0.1	99.7	1.4	227943.0
162	19.894	71	967296	0.0	0.3	0.1	99.7	1.5	292579.4
163	20.433	56	967352	0.0	0.3	0.1	99.7	1.6	250266.1
164	20.998	45	967397	0.0	0.2	0.1	99.7	1.7	217305.6
165	21.588	56	967453	0.0	0.3	0.1	99.7	1.8	295141.4
166	22.197	101	967554	0.0	0.6	0.2	99.7	2.0	577537.3
167	22.823	97	967651	0.0	0.6	0.2	99.7	2.2	604570.2
168	23.463	82	967733	0.0	0.5	0.2	99.7	2.3	555766.6
169	24.110	82	967815	0.0	0.6	0.2	99.8	2.5	603033.4
170	24.761	71	967886	0.0	0.5	0.2	99.8	2.7	564149.1
171	25.421	49	967935	0.0	0.4	0.1	99.8	2.8	417675.2
172	26.095	67	968002	0.0	0.5	0.2	99.8	3.0	625534.3
173	26.783	82	968084	0.0	0.7	0.3	99.8	3.3	826668.3
174	27.487	71	968155	0.0	0.6	0.2	99.8	3.5	771712.6
175	28.206	78	968233	0.0	0.7	0.3	99.8	3.8	921697.5
176	28.942	60	968293	0.0	0.6	0.2	99.8	4.0	758659.6
177	29.695	93	968387	0.0	1.0	0.4	99.8	4.5	1280362.6
178	30.466	67	968454	0.0	0.7	0.3	99.8	4.8	995523.9
179	31.256	52	968506	0.0	0.6	0.3	99.8	5.0	836061.7
180	32.064	78	968585	0.0	1.0	0.4	99.8	5.5	1354003.3
181	32.894	49	968633	0.0	0.6	0.3	99.8	5.7	904939.4
182	33.745	86	968719	0.0	1.2	0.5	99.8	6.3	1728592.9
183	34.619	45	968764	0.0	0.6	0.3	99.9	6.6	973803.7
184	35.518	90	968854	0.0	1.4	0.7	99.9	7.2	2103240.1
185	36.443	82	968936	0.0	1.3	0.7	99.9	7.9	2082509.6
186	37.396	78	969014	0.0	1.3	0.7	99.9	8.6	2147871.5
187	38.378	49	969063	0.0	0.9	0.5	99.9	9.0	1437230.5
188	39.393	60	969122	0.0	1.1	0.6	99.9	9.6	1912957.2
189	40.443	60	969182	0.0	1.2	0.6	99.9	10.3	2069977.9
190	41.530	67	969249	0.0	1.4	0.8	99.9	11.1	2521675.0
191	42.658	64	969313	0.0	1.4	0.8	99.9	11.9	2581007.2
192	43.831	56	969369	0.0	1.3	0.8	99.9	12.7	2470394.2
193	45.052	34	969403	0.0	0.8	0.5	99.9	13.2	1609623.3
194	46.327	26	969429	0.0	0.7	0.4	99.9	13.6	1361190.3
195	47.659	67	969496	0.0	1.8	1.2	99.9	14.8	3810975.5
196	49.055	41	969537	0.0	1.2	0.8	99.9	15.6	2539671.0
197	50.519	37	969574	0.0	1.1	0.8	99.9	16.4	2521648.0
198	52.045	52	969627	0.0	1.7	1.2	99.9	17.6	3859979.0
199	53.628	41	969668	0.0	1.4	1.0	99.9	18.6	3318252.9
200	55.272	26	969694	0.0	1.0	0.7	99.9	19.4	2311742.9
201	56.977	41	969735	0.0	1.6	1.2	100.0	20.6	3979333.9
202	58.745	41	969776	0.0	1.7	1.4	100.0	22.0	4361409.9
203	60.578	41	969817	0.0	1.8	1.5	100.0	23.5	4782711.0
204	62.480	15	969832	0.0	0.7	0.6	100.0	24.1	1908115.9
205	64.451	19	969851	0.0	0.9	0.8	100.0	24.9	2618088.2
206	66.494	11	969862	0.0	0.6	0.5	100.0	25.4	1725016.0
207	68.610	30	969892	0.0	1.7	1.6	100.0	27.0	5053486.0
208	70.803	11	969903	0.0	0.7	0.7	100.0	27.7	2082610.0
209	73.074	19	969922	0.0	1.2	1.2	100.0	28.9	3815790.0
210	75.425	11	969933	0.0	0.8	0.8	100.0	29.7	2517630.4

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (μm^3)
211	77.857	15	969948	0.0	1.1	1.2	100.0	30.8	3692252.3
212	80.374	26	969974	0.0	2.0	2.2	100.0	33.1	7108437.9
213	82.976	34	970008	0.0	2.8	3.2	100.0	36.2	10056057.7
214	85.665	7	970015	0.0	0.7	0.8	100.0	37.0	2459060.5
215	88.443	19	970034	0.0	1.7	2.1	100.0	39.1	6765284.4
216	91.310	15	970049	0.0	1.5	1.9	100.0	41.0	5955889.8
217	94.268	7	970056	0.0	0.8	1.0	100.0	42.0	3276869.4
218	97.319	11	970068	0.0	1.3	1.7	100.0	43.7	5408065.3
219	100.475	11	970079	0.0	1.4	1.9	100.0	45.6	5951574.2
220	103.762	19	970097	0.0	2.4	3.4	100.0	49.0	10924993.1
221	107.191	7	970105	0.0	1.0	1.5	100.0	50.5	4817641.5
222	110.763	11	970116	0.0	1.6	2.5	100.0	53.0	7973328.1
223	114.481	7	970124	0.0	1.2	1.8	100.0	54.9	5869008.6
224	118.346	7	970131	0.0	1.3	2.0	100.0	56.9	6483713.3
225	122.359	11	970142	0.0	2.0	3.4	100.0	60.3	10748722.2
226	126.518	15	970157	0.0	2.9	5.0	100.0	65.3	15843473.0
227	130.824	0	970157	0.0	0.0	0.0	100.0	65.3	0.0
228	135.274	4	970161	0.0	0.8	1.5	100.0	66.8	4841381.6
229	139.864	7	970168	0.0	1.7	3.4	100.0	70.1	10702252.5
230	144.590	4	970172	0.0	0.9	1.9	100.0	72.0	5912109.0
231	149.445	0	970172	0.0	0.0	0.0	100.0	72.0	0.0
232	154.422	4	970176	0.0	1.1	2.3	100.0	74.2	7202111.4
233	159.511	0	970176	0.0	0.0	0.0	100.0	74.2	0.0
234	164.698	11	970187	0.0	3.6	8.2	100.0	82.5	26212830.1
235	169.969	4	970191	0.0	1.3	3.0	100.0	85.5	9603675.9
236	175.306	0	970191	0.0	0.0	0.0	100.0	85.5	0.0
237	180.688	0	970191	0.0	0.0	0.0	100.0	85.5	0.0
238	186.091	0	970191	0.0	0.0	0.0	100.0	85.5	0.0
239	191.484	7	970198	0.0	3.3	8.6	100.0	94.1	27463542.4
240	196.832	0	970198	0.0	0.0	0.0	100.0	94.1	0.0
241	201.820	0	970198	0.0	0.0	0.0	100.0	94.1	0.0
242	206.025	0	970198	0.0	0.0	0.0	100.0	94.1	0.0
243	209.445	0	970198	0.0	0.0	0.0	100.0	94.1	0.0
244	212.355	4	970202	0.0	2.0	5.9	100.0	100.0	18729151.6
245	215.087	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
246	218.043	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
247	221.698	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
248	226.615	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
249	233.454	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
250	242.984	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
251	256.098	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
252	273.824	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
253	298.486	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
254	339.043	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
255	398.611	0	970202	0.0	0.0	0.0	100.0	100.0	0.0
256	416.065	0	970202	0.0	0.0	0.0	100.0	100.0	0.0

Particle Technology Labs

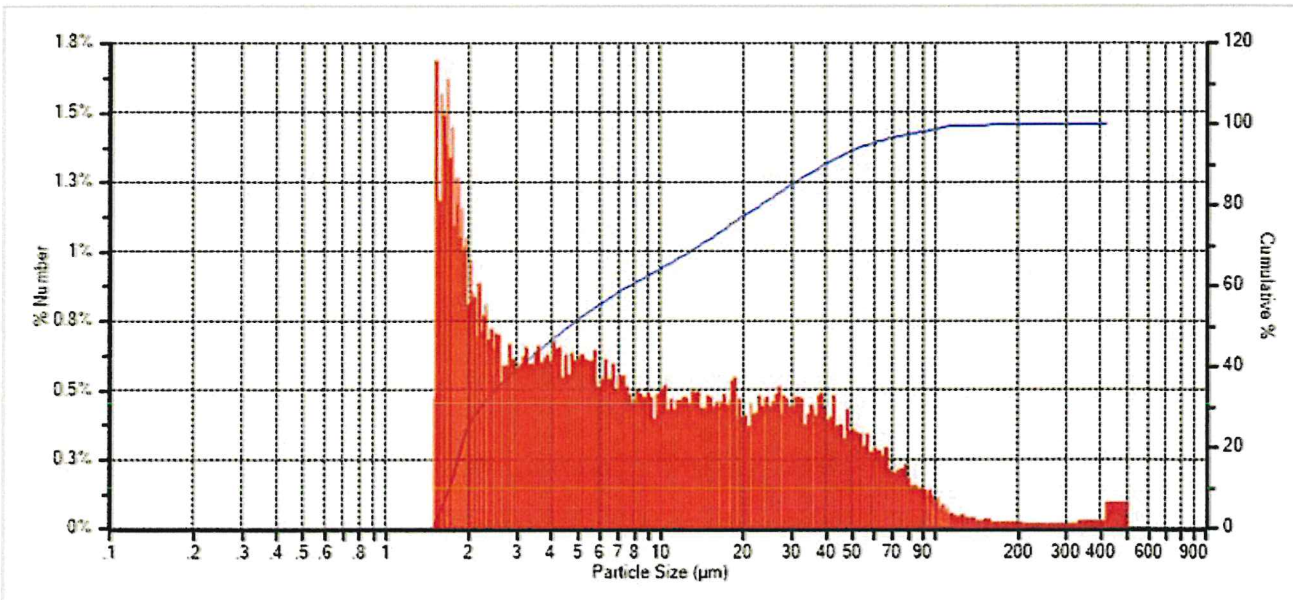
User: Samantha Ponziani
Protocol: General Analysis - Extinction
Run Date/Time: 07/22/2020 07:55
Report Date/Time: 07/22/2020, 07:58

Model number: LE400
Sensor S/N: 1805909
Calibration date: 05-19-20
Sensor mode: Extinction
Calibration Filename: 1805909-PTL (05-19-20)

Comment: CDM SMITH; Activated Sludge; 475230-49; 1.5um; SRP; 48451-21; Particle Technology Labs

Mean: 14.473 µm	Skewness: 3.0 µm	Range: 1.5 - 400 µm	Dilution Factor: 1.673
Mode: 1.534 µm	Kurtosis: 13.3 µm	Threshold: 1.5 µm	Pre DF: 1.00
Median: 4.778 µm	Fluid Volume: 60.0 ml	Channels: 197	Background: 0.0 #/ml
Standard Deviation: 21.346 µm	Sample Time: 60 sec	Total Counts: 136846	Counts/mL: 136846 #/mL

XAD--ATE--10



SRP 2020-07-22

MKW 2020-07-23

Particle Technology Labs

User: Samantha Ponziani
Protocol: General Analysis - Extinction
Run Date/Time: 07/22/202007:55
Report Date/Time: 07/22/2020, 07:58

Model number: LE400
Sensor S/N: 1805909
Calibration date: 05-19-20
Sensor mode: Extinction
Calibration Filename: 1805909-PTL (05-19-20)

Comment: CDM SMITH; Activated Sludge; 475230-49; 1.5um; SRP; 48451-21; Particle Technology Labs

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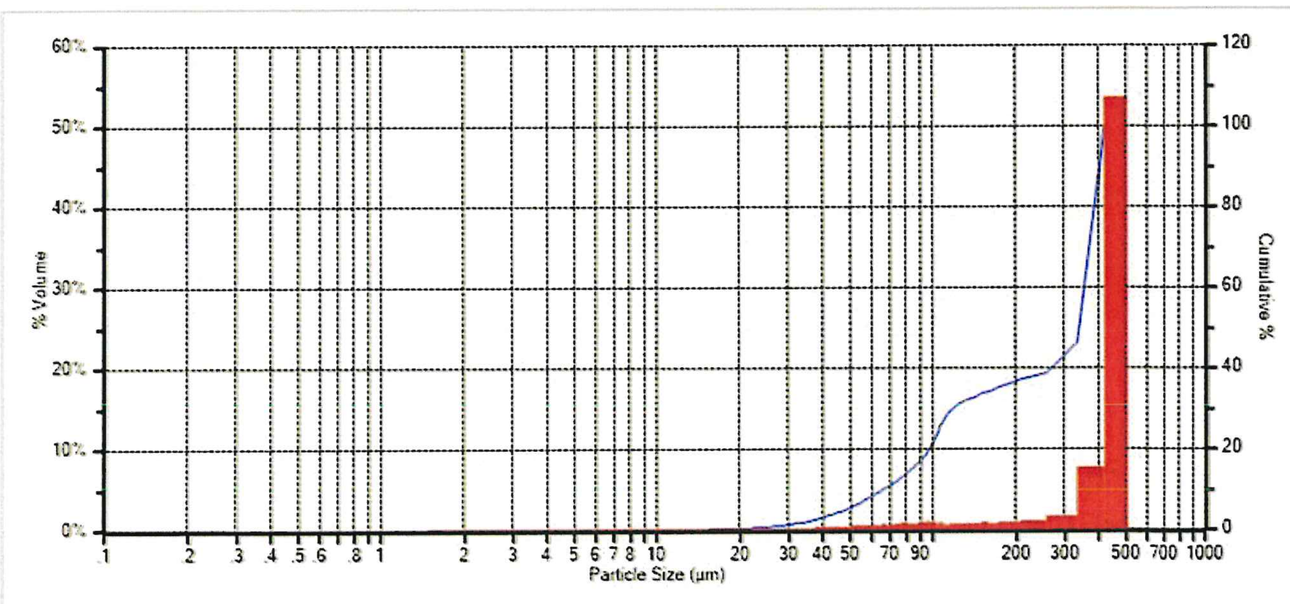
Mean: 109.840 µm	Skewness: 1.4 µm	Range: 1.5 - 400 µm	Dilution Factor: 1.673
Mode: 293.938 µm	Kurtosis: 1.7 µm	Threshold: 1.5 µm	Pre DF: 1.00
Median: 97.985 µm	Fluid Volume: 60.0 ml	Channels: 197	Background: 0.0 #/ml
Standard Deviation: 64.985 µm	Sample Time: 60 sec	Total Counts: 136846	Counts/mL: 136846 #/mL

XAD--ATE--10



Particle Technology Labs

Protocol: General Analysis - Extinction
Project: 48451-21

Model #: LE400
Sensor S/N: 1805909
Sensor mode: Extinction
Calibration file: 1805909-PTL (05-19-20)
Calibration date/time: 05-19-20
Sample Introduction: Manual
Volume sampled: 60.0 mL

Operator: SamanthaPonziani
Data collection date/time: 07:55 07/22/2020
Report Date/Time: 07:59 07/22/2020
Target concentration: 7500

Sample: XAD--ATE--10
Comment: CDM SMITH; Activated Sludge; 475230-49; 1.5um; SRP, 48451-21; Particle Technology Labs
Counts measured: 81893
Total counts (≥ 1.5 µm): 137005
Total counts/mL (≥ 1.5 µm): 137005 /mL
Pre DF: 1.00

Background concentration: 0.0 /mL
Summation voltage: 10.6 V
Extinction voltage: 10.6 V

	DN	DA	DV
10	1.709	29.930	73.702
50	4.737	92.653	385.560
90	39.727	420.363	445.526

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (µm^3)
58	1.534	2325	2971	1.7	0.0	0.0	2.2	0.0	4393.0
59	1.567	1624	4596	1.2	0.0	0.0	3.3	0.0	3274.0
60	1.600	2153	6749	1.6	0.0	0.0	4.9	0.0	4617.0
61	1.631	2049	8798	1.5	0.0	0.0	6.4	0.0	4658.0
62	1.661	1907	10705	1.4	0.0	0.0	7.8	0.0	4574.8
63	1.689	2233	12939	1.6	0.0	0.0	9.4	0.0	5632.2
64	1.715	1837	14776	1.3	0.0	0.0	10.7	0.0	4852.0
65	1.740	1989	16765	1.4	0.0	0.0	12.2	0.0	5484.1
66	1.763	1504	18269	1.1	0.0	0.0	13.3	0.0	4314.1
67	1.785	1740	20009	1.3	0.0	0.0	14.5	0.0	5177.5
68	1.805	1670	21678	1.2	0.0	0.0	15.7	0.0	5141.6
69	1.825	1606	23284	1.2	0.0	0.0	16.9	0.0	5107.8
70	1.843	1742	25026	1.3	0.0	0.0	18.2	0.0	5712.4
71	1.862	1445	26471	1.1	0.0	0.0	19.2	0.0	4886.8
72	1.881	1586	28057	1.2	0.0	0.0	20.4	0.0	5526.4
73	1.900	1310	29367	1.0	0.0	0.0	21.3	0.0	4707.7
74	1.921	1377	30744	1.0	0.0	0.0	22.3	0.0	5113.0
75	1.944	1399	32143	1.0	0.0	0.0	23.4	0.0	5383.2
76	1.970	1444	33587	1.0	0.0	0.0	24.4	0.0	5783.0
77	2.000	1111	34697	0.8	0.0	0.0	25.2	0.0	4655.9
78	2.035	1330	36027	1.0	0.0	0.0	26.2	0.0	5866.6
79	2.072	1171	37199	0.9	0.0	0.0	27.0	0.0	5451.0
80	2.110	1149	38348	0.8	0.0	0.0	27.9	0.0	5650.7
81	2.149	952	39300	0.7	0.0	0.0	28.6	0.0	4948.6
82	2.190	1218	40518	0.9	0.0	0.0	29.4	0.0	6699.0
83	2.232	972	41490	0.7	0.0	0.0	30.1	0.0	5662.2
84	2.276	1054	42544	0.8	0.0	0.0	30.9	0.0	6510.5
85	2.322	1111	43655	0.8	0.0	0.0	31.7	0.0	7282.5
86	2.369	934	44588	0.7	0.0	0.0	32.4	0.0	6500.2
87	2.418	990	45578	0.7	0.0	0.0	33.1	0.0	7332.6
88	2.469	898	46477	0.7	0.0	0.0	33.8	0.0	7078.2
89	2.521	967	47444	0.7	0.0	0.0	34.5	0.0	8115.3
90	2.576	959	48402	0.7	0.0	0.0	35.2	0.0	8577.1

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (µm³)
91	2.632	719	49122	0.5	0.0	0.0	35.7	0.0	6867.8
92	2.690	808	49930	0.6	0.0	0.0	36.3	0.0	8239.9
93	2.751	808	50738	0.6	0.0	0.0	36.9	0.0	8808.7
94	2.814	912	51650	0.7	0.0	0.0	37.5	0.0	10635.3
95	2.879	840	52490	0.6	0.0	0.0	38.1	0.0	10490.9
96	2.946	836	53326	0.6	0.0	0.0	38.7	0.0	11198.7
97	3.016	795	54121	0.6	0.0	0.0	39.3	0.0	11413.1
98	3.088	816	54937	0.6	0.0	0.0	39.9	0.0	12588.4
99	3.163	855	55792	0.6	0.0	0.0	40.5	0.0	14163.4
100	3.240	897	56689	0.7	0.0	0.0	41.2	0.0	15976.4
101	3.321	816	57505	0.6	0.0	0.0	41.8	0.0	15652.4
102	3.404	816	58322	0.6	0.0	0.0	42.4	0.0	16855.1
103	3.490	878	59200	0.6	0.0	0.0	43.0	0.0	19542.9
104	3.579	903	60103	0.7	0.0	0.0	43.7	0.0	21680.4
105	3.671	825	60928	0.6	0.0	0.0	44.3	0.0	21359.9
106	3.766	845	61773	0.6	0.0	0.0	44.9	0.0	23627.6
107	3.864	862	62634	0.6	0.0	0.0	45.5	0.0	26035.2
108	3.966	831	63466	0.6	0.0	0.0	46.1	0.0	27161.1
109	4.071	929	64394	0.7	0.0	0.0	46.8	0.0	32811.4
110	4.180	893	65288	0.6	0.0	0.0	47.4	0.0	34168.5
111	4.292	898	66186	0.7	0.0	0.0	48.1	0.0	37202.7
112	4.408	748	66934	0.5	0.0	0.0	48.6	0.0	33545.0
113	4.528	863	67797	0.6	0.0	0.0	49.3	0.0	41960.6
114	4.651	763	68560	0.6	0.0	0.0	49.8	0.0	40191.3
115	4.778	867	69427	0.6	0.0	0.0	50.4	0.0	49499.8
116	4.909	833	70260	0.6	0.0	0.0	51.0	0.0	51608.9
117	5.044	836	71096	0.6	0.0	0.0	51.6	0.0	56206.5
118	5.184	863	71960	0.6	0.0	0.0	52.3	0.0	62957.0
119	5.329	836	72796	0.6	0.0	0.0	52.9	0.0	66271.5
120	5.479	826	73623	0.6	0.0	0.0	53.5	0.0	71190.7
121	5.636	833	74456	0.6	0.0	0.0	54.1	0.0	78088.8
122	5.798	885	75341	0.6	0.0	0.0	54.7	0.0	90319.4
123	5.966	704	76045	0.5	0.0	0.0	55.2	0.0	78322.5
124	6.141	741	76786	0.5	0.0	0.0	55.8	0.0	89861.3
125	6.322	835	77621	0.6	0.0	0.0	56.4	0.0	110430.2
126	6.509	741	78362	0.5	0.0	0.0	56.9	0.0	107004.0
127	6.702	811	79173	0.6	0.0	0.0	57.5	0.0	127909.6
128	6.902	686	79859	0.5	0.0	0.0	58.0	0.0	118102.6
129	7.109	751	80611	0.5	0.0	0.0	58.6	0.0	141300.5
130	7.322	756	81367	0.5	0.0	0.0	59.1	0.0	155425.0
131	7.542	703	82069	0.5	0.0	0.0	59.6	0.0	157809.5
132	7.768	661	82730	0.5	0.0	0.0	60.1	0.0	162171.6
133	8.000	617	83348	0.4	0.0	0.0	60.6	0.0	165514.2
134	8.239	683	84030	0.5	0.0	0.0	61.0	0.0	199884.6
135	8.484	661	84691	0.5	0.0	0.0	61.5	0.0	211273.2
136	8.734	644	85335	0.5	0.0	0.0	62.0	0.0	224692.8
137	8.990	671	86006	0.5	0.0	0.0	62.5	0.0	255201.3
138	9.251	646	86652	0.5	0.0	0.0	63.0	0.0	267663.1
139	9.516	542	87194	0.4	0.0	0.0	63.3	0.0	244557.1
140	9.785	662	87856	0.5	0.1	0.0	63.8	0.0	324990.5
141	10.058	686	88542	0.5	0.1	0.0	64.3	0.0	365407.8
142	10.336	711	89253	0.5	0.1	0.0	64.8	0.0	411084.9
143	10.621	591	89844	0.4	0.1	0.0	65.3	0.1	370502.0
144	10.914	642	90486	0.5	0.1	0.0	65.7	0.1	437247.8
145	11.213	589	91075	0.4	0.1	0.0	66.2	0.1	434715.9
146	11.520	636	91711	0.5	0.1	0.0	66.6	0.1	508849.9
147	11.833	632	92343	0.5	0.1	0.0	67.1	0.1	548641.9
148	12.153	649	92992	0.5	0.1	0.0	67.6	0.1	610107.2
149	12.480	647	93640	0.5	0.1	0.0	68.0	0.1	658938.6
150	12.813	614	94254	0.4	0.1	0.0	68.5	0.1	676244.2
151	13.152	679	94933	0.5	0.1	0.0	69.0	0.1	809014.2

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (µm³)
152	13.496	668	95600	0.5	0.1	0.0	69.5	0.1	859119.8
153	13.845	679	96280	0.5	0.1	0.0	69.9	0.1	943772.1
154	14.198	596	96875	0.4	0.1	0.0	70.4	0.1	892500.7
155	14.555	594	97469	0.4	0.1	0.0	70.8	0.1	958797.6
156	14.914	656	98125	0.5	0.1	0.0	71.3	0.1	1139156.5
157	15.276	646	98771	0.5	0.1	0.0	71.8	0.1	1205240.4
158	15.639	599	99370	0.4	0.1	0.0	72.2	0.2	1199399.1
159	16.004	626	99995	0.5	0.1	0.0	72.6	0.2	1342811.2
160	16.371	604	100599	0.4	0.1	0.0	73.1	0.2	1387483.3
161	16.742	627	101227	0.5	0.1	0.0	73.5	0.2	1541395.2
162	17.116	662	101889	0.5	0.2	0.0	74.0	0.2	1739442.7
163	17.496	609	102498	0.4	0.2	0.0	74.5	0.2	1707629.3
164	17.882	634	103132	0.5	0.2	0.0	74.9	0.2	1898247.6
165	18.275	731	103863	0.5	0.2	0.0	75.5	0.3	2336511.0
166	18.678	749	104613	0.5	0.2	0.0	76.0	0.3	2557352.9
167	19.093	545	105158	0.4	0.2	0.0	76.4	0.3	1987607.3
168	19.522	639	105797	0.5	0.2	0.0	76.9	0.3	2489449.5
169	19.967	549	106346	0.4	0.2	0.0	77.3	0.4	2287155.5
170	20.427	559	106905	0.4	0.2	0.0	77.7	0.4	2493828.0
171	20.899	504	107408	0.4	0.2	0.0	78.0	0.4	2406855.6
172	21.382	614	108022	0.4	0.2	0.0	78.5	0.4	3142838.7
173	21.877	564	108586	0.4	0.2	0.0	78.9	0.5	3090870.2
174	22.384	572	109158	0.4	0.2	0.0	79.3	0.5	3359863.8
175	22.904	652	109811	0.5	0.3	0.0	79.8	0.5	4104668.2
176	23.438	604	110415	0.4	0.3	0.0	80.2	0.6	4071390.7
177	23.987	642	111057	0.5	0.3	0.0	80.7	0.6	4642226.8
178	24.551	644	111701	0.5	0.3	0.0	81.1	0.6	4990902.2
179	25.133	606	112307	0.4	0.3	0.0	81.6	0.7	5033952.6
180	25.730	627	112934	0.5	0.3	0.1	82.0	0.7	5595452.1
181	26.344	659	113593	0.5	0.4	0.1	82.5	0.8	6309864.6
182	26.975	703	114296	0.5	0.4	0.1	83.0	0.9	7221244.0
183	27.623	567	114863	0.4	0.4	0.1	83.4	0.9	6259181.3
184	28.290	654	115517	0.5	0.4	0.1	83.9	1.0	7754665.0
185	28.975	639	116156	0.5	0.4	0.1	84.4	1.1	8140243.7
186	29.680	606	116762	0.4	0.4	0.1	84.8	1.1	8290770.7
187	30.405	601	117362	0.4	0.5	0.1	85.3	1.2	8839217.0
188	31.150	644	118007	0.5	0.5	0.1	85.7	1.3	10193761.1
189	31.917	651	118657	0.5	0.5	0.1	86.2	1.4	11079180.1
190	32.706	641	119298	0.5	0.6	0.1	86.7	1.5	11737589.2
191	33.518	509	119807	0.4	0.5	0.1	87.0	1.6	10027892.4
192	34.354	562	120369	0.4	0.5	0.1	87.4	1.7	11933640.2
193	35.215	611	120979	0.4	0.6	0.1	87.9	1.8	13962823.5
194	36.102	604	121583	0.4	0.6	0.1	88.3	2.0	14879464.5
195	37.016	559	122142	0.4	0.6	0.1	88.7	2.1	14838509.6
196	37.958	656	122798	0.5	0.8	0.2	89.2	2.3	18778823.4
197	38.929	671	123469	0.5	0.8	0.2	89.7	2.5	20722595.5
198	39.931	604	124073	0.4	0.8	0.2	90.1	2.7	20133286.1
199	40.965	530	124603	0.4	0.7	0.2	90.5	2.8	19088823.0
200	42.033	547	125150	0.4	0.8	0.2	90.9	3.0	21271413.5
201	43.136	652	125803	0.5	1.0	0.2	91.4	3.3	27420173.2
202	44.276	507	126309	0.4	0.8	0.2	91.8	3.5	23038224.5
203	45.456	512	126821	0.4	0.9	0.2	92.1	3.7	25176258.0
204	46.678	442	127263	0.3	0.8	0.2	92.5	3.9	23518847.6
205	47.943	589	127852	0.4	1.1	0.3	92.9	4.2	33978066.8
206	49.254	482	128334	0.4	1.0	0.3	93.2	4.5	30144740.0
207	50.620	485	128819	0.4	1.0	0.3	93.6	4.8	32949149.7
208	52.056	472	129291	0.3	1.0	0.3	93.9	5.1	34846482.1
209	53.576	467	129757	0.3	1.1	0.3	94.3	5.5	37584697.5
210	55.181	407	130164	0.3	1.0	0.3	94.6	5.8	35765009.7
211	56.870	468	130632	0.3	1.2	0.4	94.9	6.2	45112175.0
212	58.643	376	131009	0.3	1.1	0.4	95.2	6.6	39749140.9

Channel	Diameter (µm)	Counts (#)	Cumulative (# ≤ Dia.)	Number (%)	Area (%)	Volume (%)	Number (%≤ Dia.)	Volume (%≤ Dia.)	Abs. Volume (μm^3)
213	60.500	391	131400	0.3	1.2	0.4	95.5	7.0	45391882.9
214	62.439	385	131785	0.3	1.2	0.4	95.7	7.4	49044610.0
215	64.458	361	132146	0.3	1.2	0.5	96.0	7.9	50672285.5
216	66.552	396	132543	0.3	1.4	0.6	96.3	8.4	61196417.7
217	68.718	293	132836	0.2	1.1	0.5	96.5	8.9	49744034.0
218	70.950	266	133102	0.2	1.1	0.5	96.7	9.3	49743624.1
219	73.239	286	133388	0.2	1.3	0.5	96.9	9.9	58846364.8
220	75.578	293	133681	0.2	1.4	0.6	97.1	10.5	66178803.8
221	77.956	311	133992	0.2	1.5	0.7	97.3	11.2	77186660.5
222	80.358	248	134239	0.2	1.3	0.6	97.5	11.8	67272676.0
223	82.771	207	134447	0.2	1.2	0.6	97.7	12.4	61593834.6
224	85.175	206	134653	0.1	1.2	0.6	97.8	13.0	66577365.9
225	87.550	191	134843	0.1	1.2	0.6	98.0	13.6	67013101.2
226	89.871	202	135046	0.1	1.3	0.7	98.1	14.3	76936590.7
227	92.110	184	135230	0.1	1.3	0.7	98.2	15.0	75301265.0
228	94.234	166	135395	0.1	1.2	0.7	98.4	15.6	72569197.4
229	96.207	186	135581	0.1	1.4	0.8	98.5	16.4	86581859.6
230	97.985	166	135747	0.1	1.3	0.7	98.6	17.1	81584408.0
231	99.568	159	135906	0.1	1.3	0.7	98.7	17.9	82143484.1
232	100.997	132	136038	0.1	1.1	0.6	98.8	18.5	71291453.6
233	102.305	149	136187	0.1	1.3	0.8	98.9	19.3	83476277.4
234	103.516	97	136284	0.1	0.9	0.5	99.0	19.8	56356007.4
235	104.662	92	136376	0.1	0.8	0.5	99.1	20.3	55235654.6
236	105.780	109	136485	0.1	1.0	0.6	99.2	20.9	67392732.6
237	106.915	115	136600	0.1	1.1	0.7	99.2	21.6	73867995.8
238	108.122	107	136707	0.1	1.0	0.6	99.3	22.2	70861116.9
239	109.464	79	136786	0.1	0.8	0.5	99.4	22.7	54000513.0
240	111.017	94	136879	0.1	0.9	0.6	99.4	23.3	67118521.9
241	112.869	62	136941	0.0	0.6	0.4	99.5	23.8	46602980.4
242	115.123	75	137017	0.1	0.8	0.5	99.5	24.3	60142760.0
243	117.897	65	137082	0.0	0.7	0.5	99.6	24.8	55982891.9
244	121.327	57	137139	0.0	0.7	0.5	99.6	25.3	53191221.9
245	125.571	64	137202	0.0	0.8	0.6	99.7	25.9	65908285.5
246	130.808	49	137251	0.0	0.7	0.5	99.7	26.4	56857571.7
247	137.242	47	137298	0.0	0.7	0.6	99.7	27.0	63403012.6
248	145.107	35	137333	0.0	0.6	0.5	99.8	27.5	56204649.7
249	154.666	42	137375	0.0	0.8	0.7	99.8	28.2	81024151.1
250	166.219	28	137403	0.0	0.6	0.6	99.8	28.9	68388278.5
251	180.105	30	137433	0.0	0.8	0.8	99.8	29.7	92116703.3
252	197.823	23	137457	0.0	0.8	0.9	99.9	30.6	94939037.8
253	232.370	18	137475	0.0	0.8	1.1	99.9	31.7	120898343.9
254	293.938	17	137492	0.0	1.2	2.0	99.9	33.7	222460931.1
255	374.243	35	137527	0.0	4.0	8.8	99.9	42.5	964199064.4
256	408.690	0	137492	0.0	0.0	0.0	99.9	33.7	0.0