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ClearCove Organics Harvester Demonstration at the Ithaca Area Wastewater Treatment Facility

Final Report

June 2015

Report Number 15-22

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ClearCove Organics Harvester Demonstration at the Ithaca Area Wastewater Treatment Facility

Final Report

Prepared for:

New York State Energy Research and Development Authority

Albany, NY

Kathleen O'Connor
Senior Project Manager

Prepared by:

ClearCove Inc.

Alex Wright
Project Manager, ClearCove

Terry Wright
CTO & Founder, ClearCove

Mark Greene, Ph.D.
Subject Matter Expert on Anaerobic Digestion, O'Brien & Gere Engineers

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Notice

Abstract

Conventional primary treatment typically removes less than 25-35% of the organics at the head of the wastewater treatment plant. The ClearCove Organics Harvester (OH), an innovative process piloted at the Ithaca Area Wastewater Treatment Facility (IAWWTF), proved that it removes the majority of organics in the primary stage. In the demonstration project, increased biogas generation from the pilot system was realized and anticipated energy savings associated with secondary treatment upon installation of a full-scale system were calculated. This project was validated by measurements of the removal capabilities of the OH pilot in combination with the pilot-scale anaerobic digesters. An increase of methane production from primary sludge by 240-520% was shown and a 52% reduction of energy associated with secondary aeration upon installation of a full-scale system was calculated. Should a full-scale system be installed at the IAWWTF, total methane production is anticipated to increase by 180-320%, depending on the valuation matrixes and that the IAWWTF would be capable of producing more energy than it consumes.

Keywords

Enhanced primary treatment, anaerobic digestion, wastewater, biogas, renewable energy, chemically enhanced primary treatment, OH, headworks, energy reduction, net-zero, BOD removal, BOD interception, carbon diversion, biochemical methane potential, BMP, energy generation

Acknowledgments

This demonstration project would not have been possible without the assistance and support of Dan Ramer and the operators/staff of the IAWWTF and O'Brien & Gere Engineers; Kathleen O'Connor of NYSERDA; and the members of the Project Advisory Committee, including Jason Turgeon, Lauren Fillmore, Rich Lyons, Ralph Eschborn, and Jim Fitzpatrick. We also sincerely thank Mayor Svante Myrick, his staff, and the citizens of Ithaca, NY for their hospitality.

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Acronyms and Abbreviations

µm	micrometer
ADG	anaerobic digester gas
AMPTS II	Automatic Methane Potential Test System
BFP	belt filter press
BMP	biochemical methane potential
BNR	biological nutrient removal
BOD_5	biochemical oxygen demand, 5-day
CEPT	chemical enhanced primary treatment
CH_4	methane
cng	compressed natural gas
CO_2	carbon dioxide
COD	chemical oxygen demand
EPA	U.S. Environmental Protection Agency
$FeCl_3$	ferric chloride
FOG	fats, oils, and grease
FPS	feet per second
ft	foot or feet
GPD	gallons per day
GPM	gallons per minute
HMI	Human Machine Interface
hr	hour
IAWWTF	Ithaca Area Wastewater Treatment Facility
IFS	influent feed system
kcf	thousand cubic feet
kWh	kilowatt-hour
lb	pound
mg/L	milligram per liter
MGD	million gallons per day
mL	milliliter
nmL	normalized milliliter
NRV	no recorded values
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
OH	ClearCove Organics Harvester
PD	pilot digester
PLC	Programmable Logic Controller
RAS	return activated sludge

$SBOD_5$	soluble biochemical oxygen demand, 5-day
SCF	cubic feet at standard conditions
SCP	sludge cleaning and enhancement process
SF	square foot
SOR	surface overflow rate
TKN	total Kjeldahl nitrogen
TP	total phosphorus
TS	total solids
TSS	total suspended solids
UVAS	ultraviolet absorption spectrometer
VFD	variable frequency drive
VS	volatile solids
VSS	volatile suspended solids
WAS	waste activated sludge
WWTP	wastewater treatment plant

Summary

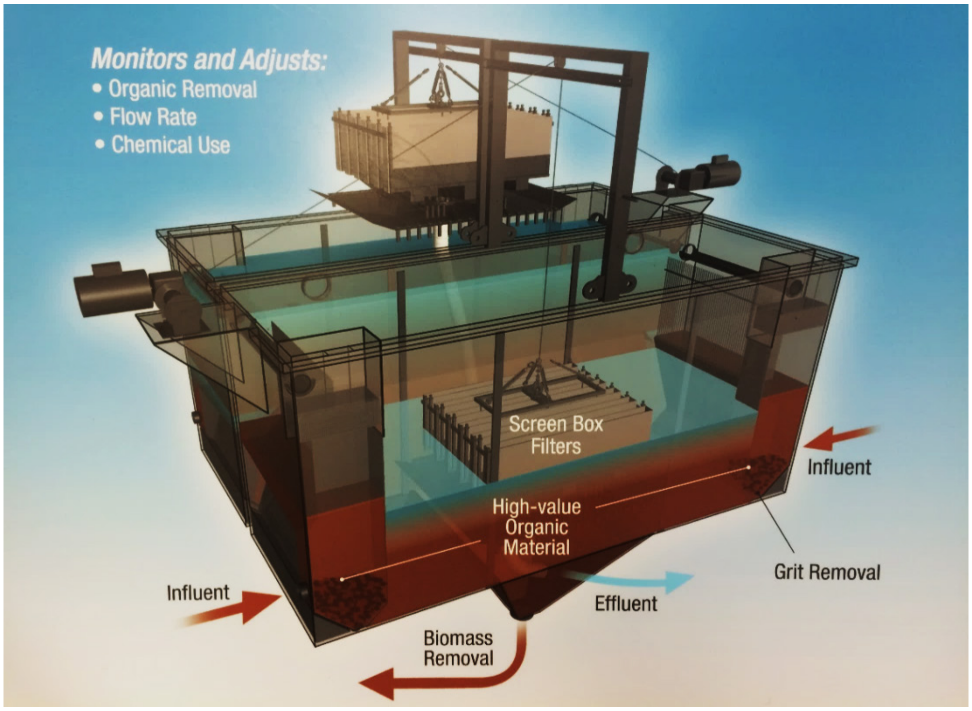
The ClearCove Organics Harvester for Primary Treatment (OH) technology is a complete headworks and primary treatment solution that combines primary clarification; flow equalization; fine screening; grit removal; fiber removal; fats, oils, and grease (FOG) removal; and floatables removal in a single tank. Conventional headworks and primary treatment typically involve separate pieces of equipment to perform all such treatment capabilities and may carry high capital and footprint requirements. Conventional primary treatment captures approximately 30% of the organics or biochemical oxygen demand (BOD) at the front of the plant, while OH captures more than double that amount, or 65-70% of the BOD. This technology of enhanced organics capture at the head of the wastewater treatment plant results in increased the biogas production from anaerobic digestion by preserving the high-energy value organics in the primary stage and should subsequently result in reduced energy consumption in the activated sludge process.

A physical, chemical process that combines natural gravity settling with an innovative screening method to filter out particulates, the ClearCove OH uses very little energy. Raw sewage enters at either end of the tank through grit inlet boxes and influent feed systems, and then is settled and decanted. Solids and organics are separated from the water using gravity and a 50-micrometer (µm; .05 mm) decanting screen. A diagram of the OH unit is shown in Figure S-1.

The settled organics and solids are removed from the bottom of one of two or more tanks and sent to a "sludge classifying press" or thickener, and then on to anaerobic digestion for energy generation. The remaining water or primary effluent is sent to downstream secondary treatment. The OH system always includes at least two tanks operating side by side; one tank fills quickly and settles, while the other decants and discharges effluent. Maximum pumping velocity fills the tank and controlled, consistent pumping delivers primary effluent to the secondary process, achieving the higher organics removal. In a conventional primary clarifier, the wastewater always has a constant forward velocity, entering at one end of the tank and flowing out the other. With two tanks operating in parallel, the OH can completely stop the water in one tank (or more for multiple tank installations), allowing the lighter, colloidal organic particles to coagulate and be captured in the sludge blanket at the bottom of the tank.

Figure S-1. The Organics Harvester (OH) Unit

Two tanks (back and foreground) combine headworks and primary treatment capabilities while reducing energy consumption.



S.1 Project Description

The goals of this project were to demonstrate that the:

- Majority of wastewater organics (i.e., 5-day BOD or BOD_5) could be removed by the OH technology at the primary treatment stage.
- Removal of the majority of the organics at the primary treatment stage should lead to reduced energy requirements for subsequent activated sludge secondary treatment.

Primary sludge (i.e., the organics removed at the primary treatment stage) have much higher energy content than organics removed at later stages in the treatment process and should, therefore, produce greater volumes of biogas upon digestion than those organics removed later. To accomplish these goals, ClearCove deployed its 24,000 gallon per day OH pilot unit at the Ithaca Area Wastewater Treatment Facility (IAWWTF) in conjunction with four 350-gallon pilot-scale anaerobic digesters designed and built by O'Brien & Gere Engineering. Biochemical methane potential (BMP) testing was also run in parallel to the pilot digester units to correlate and act as a backup to biogas generation data collection.

The OH pilot pumped raw influent wastewater from the influent channel of the IAWWTF, upstream of any chemical addition. The OH's influent and effluent were tested for a number of parameters to compare the unit's performance to conventional primary clarifiers and to calculate what the mass balance of the IAWWTF would be if a full-scale OH was installed.

The sludge captured in the OH then ran through ClearCove's sludge cleaning and enhancement process (SCP), which "cleans" and conditions the sludge by removing all "trash," hair, and fiber and pressing addition high value organics for increased methane production in the anaerobic digesters. This conditioned sludge was fed to the pilot digesters in parallel with the IAWWTF's primary and thickened sludge to compare biogas generation results. The four pilot digesters were fed as follows:

- **Digester 1 IAWWTF Thickened Sludge** – same sludge the IAWWTF feeds its full-scale digester, a combination of IAWWTF primary and secondary sludge collected from the full-scale sludge thickening tank. This one was the control, fed at the same rate as the full scale digester at 50 pounds Volatile Solids/day/thousand cubic feet (lb VS/day/kcf) digester volume.
- **Digester 2 IAWWTF Primary Sludge** – sludge from the IAWWTF conventional primary clarifiers. The sludge was filtered to remove gross inorganics to prevent clogging in the feeding and circulation process. Fed at the same rate as the full scale digester at 50 lb VS/day/kcf digester volume.
- **Digester 3 ClearCove OH Sludge –** sludge from the OH pilot after being conditioned by the SCP. Fed at the same rate as the full scale digester at 50 lb VS/day/kcf digester volume.
- **Digester 4 ClearCove OH Sludge** – same sludge as Digester 3, but fed at twice the daily pounds of volatile solids (VS) as Digester 3 at 100 lb VS/day/kcf digester volume.

The BMP experiment was performed to validate and correlate the data of the pilot digester. The same sludge types listed were tested using the BMP equipment.

S.2 Project Results

S.2.1 OH Pilot Performance

Ten 24-hour composite samples were collected of the OH influent and effluent and tested for a number of parameters to determine the performance in comparison to conventional primary treatment. Table S-1 presents the average removal results of the 24,000 gallons per day (GPD) OH pilot unit in comparison to the removal rates of conventional primary clarifiers from literature. The OH achieved enhanced removal across all parameters tested versus the conventional method. During the demonstration period, the

IAWWTF experienced an internal process upset and several plant upgrades that affected the plant's primary clarifier effluent values. Sample data during multiple days involving these instances showed higher primary effluent values than influent for all measured parameters and were due to side streams returned to the head of the primary clarifiers.

The OH pilot removal performance results for BOD were used in the calculation of aeration energy consumption savings. The greater the removal of BOD, the greater the expected energy reduction is during aeration.

The OH can operate with chemical addition or without, as necessary. A nonchemical pilot test yielded 46% chemical oxygen demand (COD) removal for Ithaca WWTF with two data points. The ClearCove pilot has been demonstrated at multiple locations across New York State. Table S-1 shows the nonchemical removal average from those sites, including:

- Nott Road Wastewater Treatment Plant – Guilderland, NY.
- Oneida County Water Pollution Control Plant – Utica, NY.
- Macedon Wastewater Treatment Plant – Macedon, NY.

Table S-1. OH and Conventional Primary Clarification Removal Rate Comparisons

	BOD	SBOD	TSS	VSS	COD	TP	TKN
OH 80 mg/L FeCl[c] + 0.25 mg/L polymer	67%	25%	84%	85%	62%	72%	26%
OH – No Chemical (avg. 4 Pilots)[c]	55%	12%	71%	68%	26%	31%	21%
Conv. Primary From Literature	30%[a]		58%[a,b]		30%[a]		

a Wilson, Thomas et al. "Clarifier Design: Manual of Practice." *Water Environment Federation*, 2005

b Puig, S. "The Effect of Primary Sedimentation on Full-Scale WWTP Nutrient Removal Performance. " *Water Research*, 2010, 3375-384.

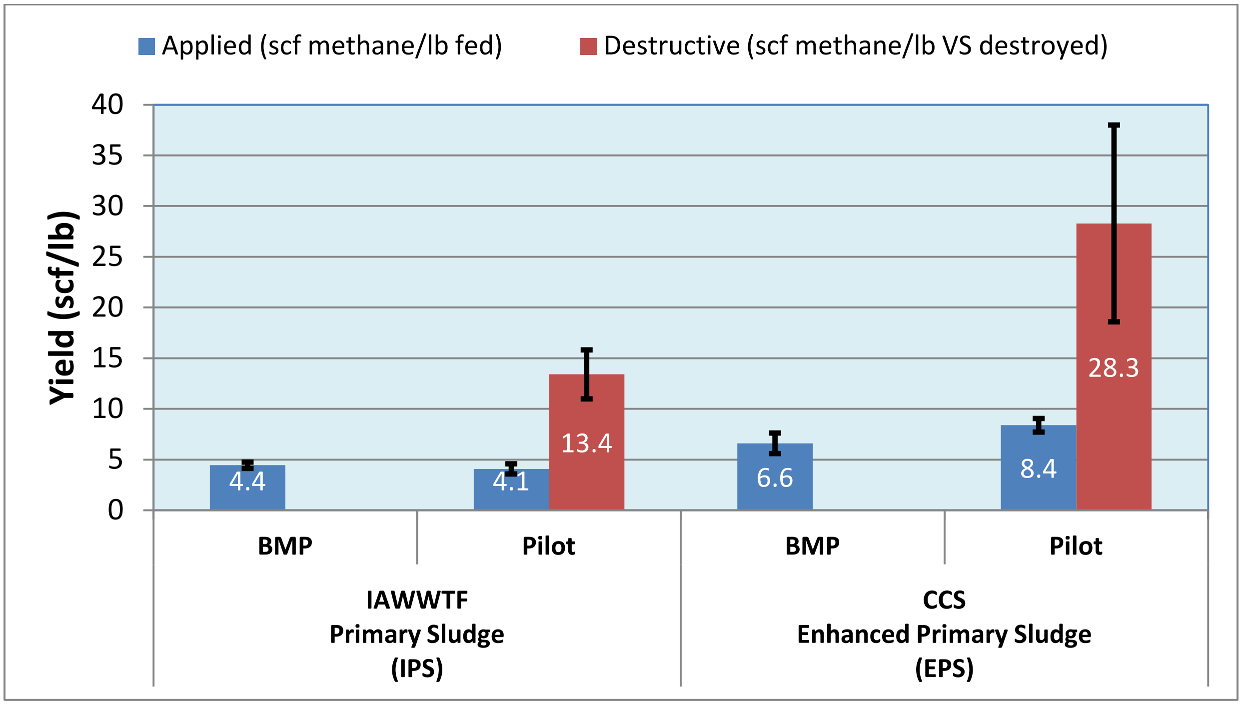
c Average No – Chemical removal: Ithaca NY, Nott Road (Albany County NY), Macedon, NY, Oneida County NY WWTF's

S.2.2 Pilot Digester and BMP Testing Performance

As previously stated, the benefits of biogas generation from OH sludge were validated using pilot digesters and corroborated using BMP testing. Pilot digester results showed that the OH sludge produces over two times the methane yield of the facility's primary sludge per pound of VS fed to the digester, and per pound of VS destroyed in the digester. This increased yield combined with the enhanced capture of VSS in the OH will contribute to the increased methane projections later in the report. Figure S-2 compares the methane yield between the two sludge types from the conventional and OH.

Figure S-2. Pilot Digester and BMP Methane Yield Comparisons

Error bars in the above graph represent the 95% confidence interval.



Factors that contribute to the increased methane yield of the enhanced primary sludge are:

- Enhanced capture of colloidal particles in the OH unit.
- Higher BOD concentration of the OH sludge.
- Reduced particle size of the enhanced primary sludge versus Ithaca's conventional primary sludge. [1,2]
- Higher available organic concentration using the sludge cleaning and enhancement process (SCP), releasing trapped organics.
- IAWWTF's poor thickener performance creates high solids streams recirculating to primary clarifiers.

These factors are discussed more in Section 5.

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[1] Palmowski, L.M. and J.A. Muller, "Influence of the size reduction of organic waste on their anaerobic digestion," Water and Technology, IWA Publishing

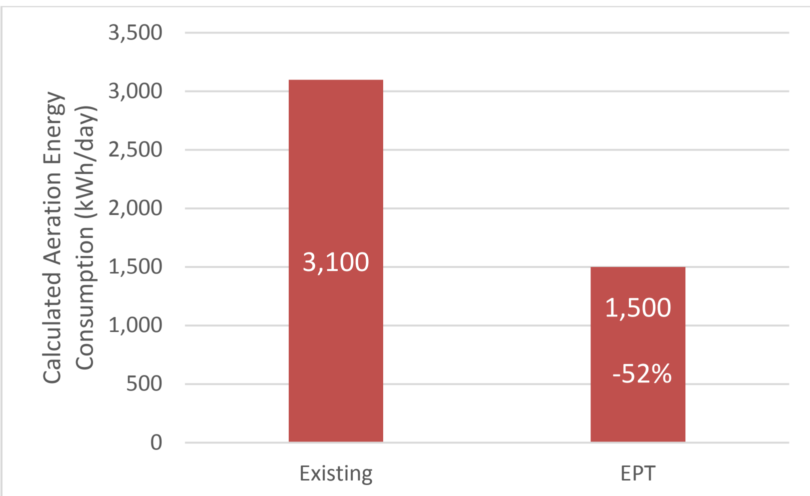
[2] Izumi, Kouichi, Yuki Okishio et al., "Effects of particle size on anaerobic digestion of food waste," International Biodeterioration & Biodegradation

S.2.3 Positive OH Operations Projected at IAWWTF

There are positive expectations for installing full-scale OH technology at the IAWWTF. Calculations from the OH pilot revealed the new mass and energy balances would be improved at the facility.

The OH achieved 67% BOD removal rate compared to the average 30% by a conventional primary clarifier. Should a full-scale OH system be installed at the IAWWTF and extrapolating from the data collected during the demonstration, it is calculated that the increase in BOD removal could reduce aeration energy consumption by 52%, as shown in Figure S-3. The facility could completely turn off one of its aeration blowers which otherwise would run around the clock. This change correlates to a minimum of $56,000/year in energy savings ($.095 kWh) to the IAWWTF.

Figure S-3. Calculated Aeration Energy Impact



The scenarios illustrated in Figure S-4 and discussed in further detail later the report in regards to facility energy impacts are as follows:

- Current IAWWTF from Plant Residuals – The current conventional IAWWTF process.
- OH w/ IAWWTF Current Thickener – The OH installed with the IAWWTF's current thickener still in place.
- OH w/ SCP – The OH installed as well as the SCP in place of the IAWWTF gravity thickener. The SCP would provide the thickening as well as the conditioning of the sludge to provide an improved sludge to the anaerobic digester.

When installed at full scale, the ratio of primary to secondary sludge will shift due to the enhanced capture of solids in the OH system demonstrated through the total suspended solids (TSS) and volatile suspended solids (VSS) removal rates. As shown in Figure S-4 and Table S-2, the increased primary sludge volume in combination with the increased methane yield of the enhanced primary sludge as extrapolated from the demonstration data are expected to result in the plant producing 260 - 520% more methane from its primary sludge.

Figure S-4. Calculated Methane Generation from Only Primary Sludge

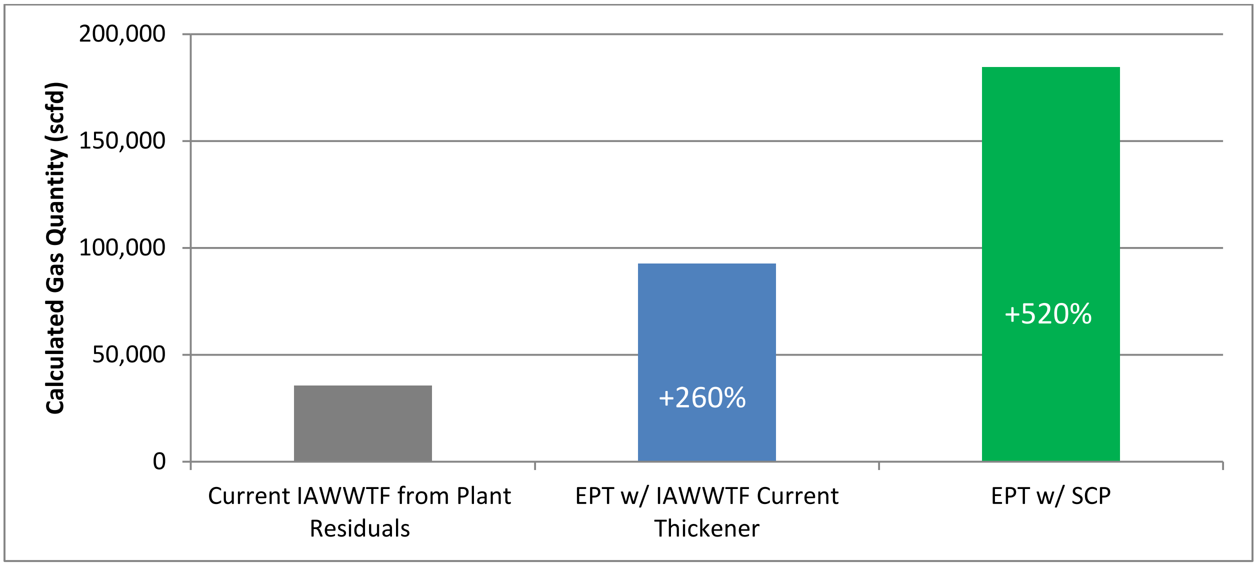


Table S-2. Calculated Impact of Methane Generation from Primary Sludge

PARAMETER	Existing	OH with Current Thickener	OH with SCP
Volatile solids loading (lb/day)	8,700	11,000	9,000
Methane generation (cu.ft/day)	35,700	93,600	184,600

The methane generation from the current plant residuals came from historical plant biogas data. The methane generation values of the OH scenario were calculated using the 28.3 scf CH_4/lb VS destroyed as found in the pilot digester results shown in Figure S-2, as well as the VSS capture of 85% as collected by the OH pilot shown previously in Table S-1. It was calculated that this additional methane generation should allow the facility to generate 4.0 - 7.0 GWh/year.

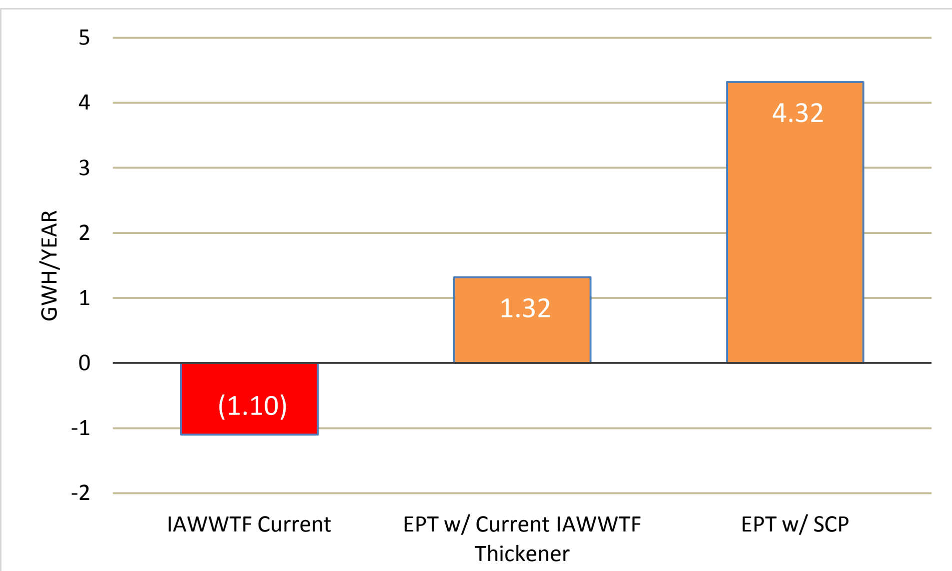
The IAWWTF currently doses 50-100 GPD of ferrous chloride at the front of the plant and 400-500 GPD of ferric chloride in its Actiflo process for phosphorus polishing, With the installation of the OH, this chemical usage would not be increased; instead, the 500 GPD of ferric chloride would be dosed through the OH at the front of the facility. This would potentially offset the need for the additional 50-100 GPD of ferrous sulfate being added now. The cost to the facility would remain the same with potential for being less if the ferrous sulfate use is eliminated.

S.2.4 Future Energy Impact

The calculated energy reduction benefits together with the calcuated increased energy production potential enabled by installation of a full-scale OH system could bring the IAWWTF not only into a net-zero energy position, but to net positive, where the facility generates more energy than it consumes onsite. It was calculated that with the installation of a full-scale OH system, the IAWWTF would move from consuming approximately 1.1 GWh/year, to generating between 1.25 – 4.35 GWh/year more than it consumes, as illustrated in Figure S-5.

Figure S-5. Calculated IAWWTF Net Energy Balance

Refer to Table 14 for details and Appendix H for calculations. Visit https://www.youtube.com/watch?v=sSZIjl0sypQ to see a video of ClearCove NYSERDA Demonstration Project at IAWWTF.



1 Introduction

The purpose of this NYSERDA-supported project was to assess the energy reduction and energy production benefits of the ClearCove Inc. Organics Harvester (OH) technology. In addition, plant-wide impacts were calculated based on a future installation of a full-scale OH system.

The primary partners in this project were ClearCove, the Ithaca Area Wastewater Treatment Facility (IAWWTF), and O'Brien & Gere Engineers.

The primary goals of this project were to demonstrate that the:

- Majority of wastewater organics (i.e., BOD_5 could be removed by the OH technology at the primary treatment stage.
- Removal of the majority of the organics at the primary treatment stage should lead to reduced energy requirements for subsequent activated sludge secondary treatment.

To accomplish these goals, ClearCove worked with O'Brien & Gere Engineers and the IAWWTF to implement a pilot system that included the ClearCove OH, sludge cleaning and enhancement process (SCP), and pilot anaerobic digesters.

1.1 Ithaca Area Wastewater Treatment Facility (IAWWTF)

The IAWWTF was constructed in 1987, is permitted to treat 13.1 million gallons per day (MGD), receives an average flow of 6.5 MGD, and has the capacity to treat a maximum storm flow of 28 MGD (Figure 1). The liquid treatment train consists of an influent building with coarse mechanical bar screens, primary clarifiers, activated sludge secondary treatment, secondary clarification, a high rate ballasted flocculation clarifier to reduce phosphorus loading to Cayuga Lake, and disinfection. The solids treatment train consists of primary and secondary sludge from the respective clarifiers, along with backwash from tertiary clarification are combined in the gravity thickener prior to anaerobic digestion and then pressed. Ithaca has separate storm and sewer collection systems. The IAWWTF is fed primarily residential wastewater as there is little industry in the area. The facility is affected by infiltration and inflow during storm events with flows increasing from 6.4 MGD to 20+ MGD.

Figure 1. Aerial View of IAWWTF Site

The wastewater entering the IAWWTF is impacted by the local college sessions, storm events, and periodic discharges from waste haulers into the Influent Building (IB). On occasion, the facility returns tank cleaning and process drain liquids to the IB for reprocessing through the plant. As the demonstration was performed at a fully operational wastewater treatment facility, these types of real-world scenarios were expected but did not affect the OH performance. The IAWWTF is currently concluding an extensive plant improvement program that included upgrades to its anaerobic digesters, aeration diffusers and blowers, anaerobic digester gas (ADG)-fueled electric generators, and a food waste receiving facility, all with the purpose of bringing the plant closer to net-zero energy consumption.

1.2 Organics Harvester Technology

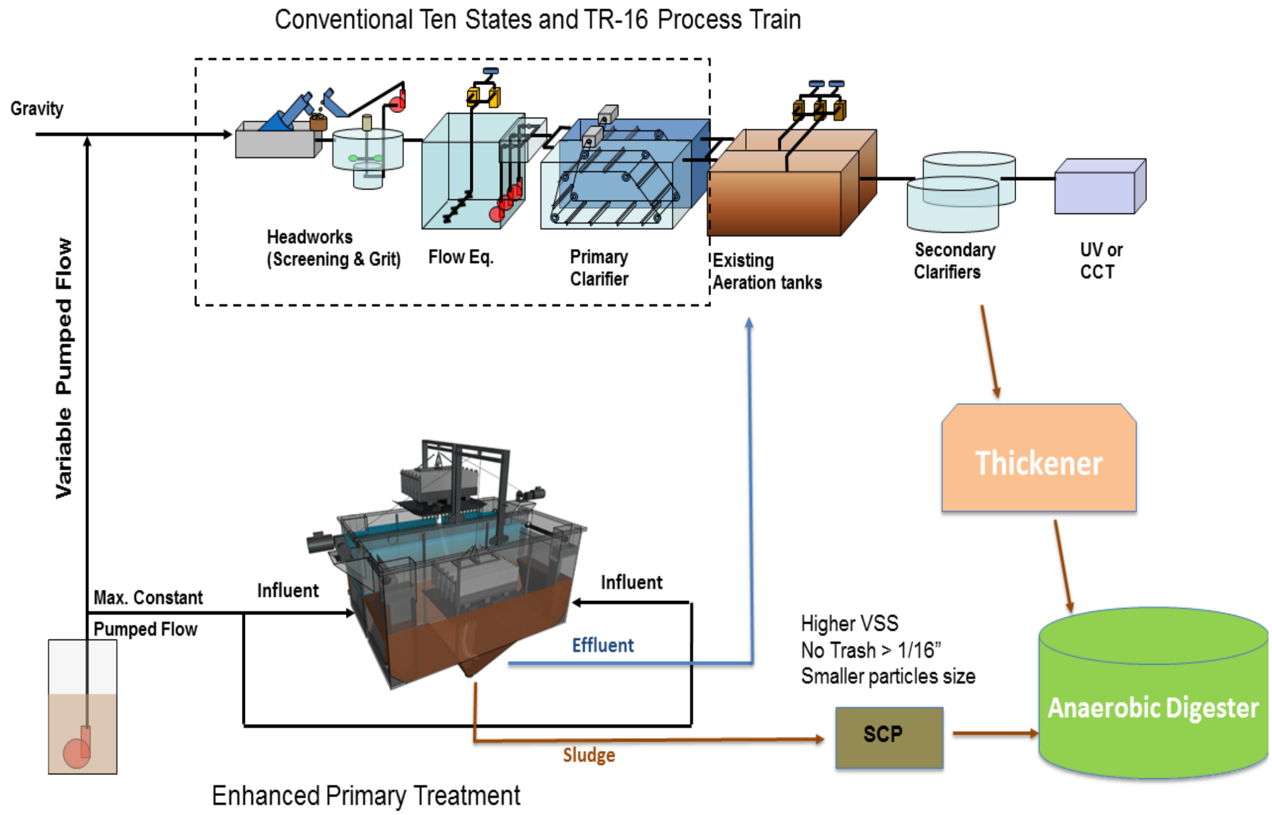
The ClearCove OH is a physical/chemical process that removes the majority of organics and solids at the head of the wastewater treatment plant. The OH performs flow equalization, grit and inorganic removal, gross solids separation, ultrafine screening, fiber removal, FOG removal and primary clarification in a single process and tank, rather than the conventional method of separate steps and multiple pieces of equipment. By removing the organics at the head of the wastewater treatment plant, it reduces the organic load going downstream to secondary treatment. In turn, this process reduces the energy required to convert the organics to biomass and CO_2, and increases the amount of primary sludge sent to the anaerobic digester for biogas generation. The redirection of high value organics generates methane in an anaerobic digester. Figure 2 provides an illustration of the change in primary treatment offered by the OH.

1.3 Sludge Cleaning and Enhancement Process

The raw sewage is pumped into the OH tank, which performs grit removal, screening, and flow equalization in the same tank. This process results in the capture of solids that are not desirable to feed to the digester. As part of the ClearCove OH, the SCP is used to provide conditioned sludge directly to the digester while removing the grit, fiber, hair and large solids from the lower volume solids which are steps performed by larger liquid stream bar racks, screens, and grit removal equipment.

The SCP is a sludge processing and "cleaning" technology that mechanically removes the larger inorganics (trash, hair, etc.) from sludge captured in the influent feed system (IFS) and main chamber of the OH. At the same time, it shears the encased organics to increase the organic concentration of the sludge and reduce particle size. This step increases the capacity of the anaerobic digester by removing trash from the sludge and by raising the production and rate of biogas generation of the sludge produced with higher organics. More details and images of the SCP are included in Section 3.

Figure 2. Schematic Showing OH Process Train Versus Conventional



2 Description of Project

To achieve the project goals, as well as to address several site-specific questions, the following were evaluated during the course of the project:

- Aeration energy savings as a result of the enhanced BOD removal.
- Biogas generation increase as a result of the enhanced primary sludge captured.
- Relative capacity increase of the digester as a result of the increased sludge biodegradability and the improved inorganic removal by the sludge classifying press.
- Sludge processing impact as a result of higher percent solids value of the ClearCove sludge and the improved ratio of primary to secondary sludge.
- Chemical cost impact of the new process in comparison to the current chemical usage of the IAWWTF.

This work was accomplished by two groups. O'Brien & Gere designed, installed and provided operational oversight of the pilot digesters; evaluated the pilot digester performance; analyzed the gas generation data; and performed the energy reduction and energy generation calculations for the IAWWTF. The firm designed 350-gallon digesters to simulate the full-scale IAWWTF digesters, mirroring their loading, pH and temperature. ClearCove provided the pilot OH, pilot SCP, thickening tanks used on the post-SCP and IAWWTF primary sludge; operated the OH, SCP, pilot digesters and BMP unit; performed internal process testing for control and optimization sample collection for certified laboratory testing; maintained the pilot equipment; and coordinated plant activities with the IAWWTF.

The OH 24,000-GPD unit operated 24 hours per day for six months at the IAWWTF with minimal shutdown over the course of the project. The OH unit operated to generate sludge, which was then conditioned by the SCP and fed to the pilot digesters and BMP experiment. A 900-gallon tank, utilized to collect OH sludge, limited the OH treatment capacity to an average of 12,000 GPD, which prevented accumulating too much sludge and potentially displacing decant.

This demonstration was conducted from April to October 2014. During this time frame, the IAWWTF flow and organic loads were influenced by several colleges being out of session during the summer. A new solids waste facility also came online in mid-summer while periodic loads from liquid waste haulers were discharged into the headworks building prior to the pilot's influent feed pumps.

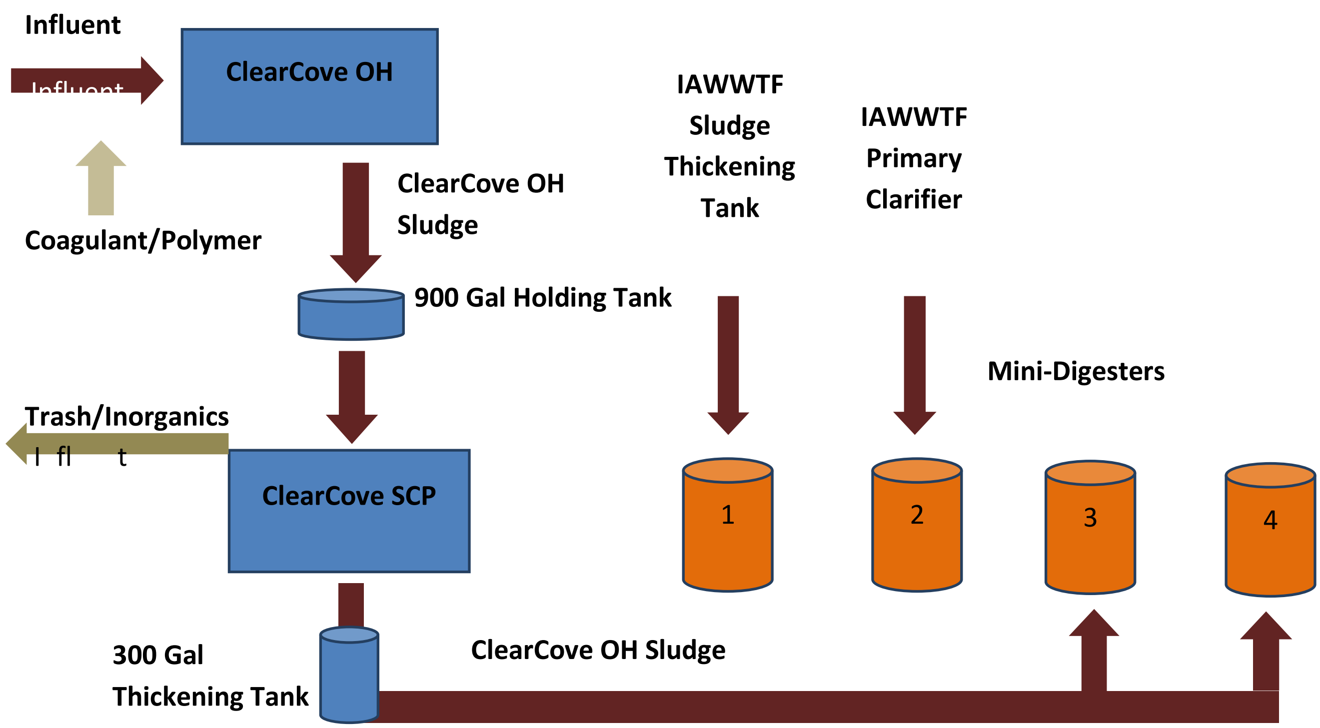
3 Description of System

The entire pilot system consists of the OH unit, SCP unit, BMP unit, and four pilot-scale anaerobic digesters. The OH unit receives and treats the raw sewage. The sludge captured in the OH is sent to a holding tank and then to the SCP for conditioning. After the sludge has been processed by the SCP, it is sent to a thickening tank to up to 3% solids. After the thickening tank, the sludge is transported to the feed tanks of the two pilot digesters and BMP unit. A simple schematic of the system is illustrated in Figure 3.

Figure 3. OH Pilot System Schematic

Visit http://clearcovesystems.com/the-idea/settling-system-design/ to see an animation of the ClearCove OH process.

Visit https://www.youtube.com/watch?v=sSZIjl0sypQ to see a video of the pilot system at the IAWWTF.

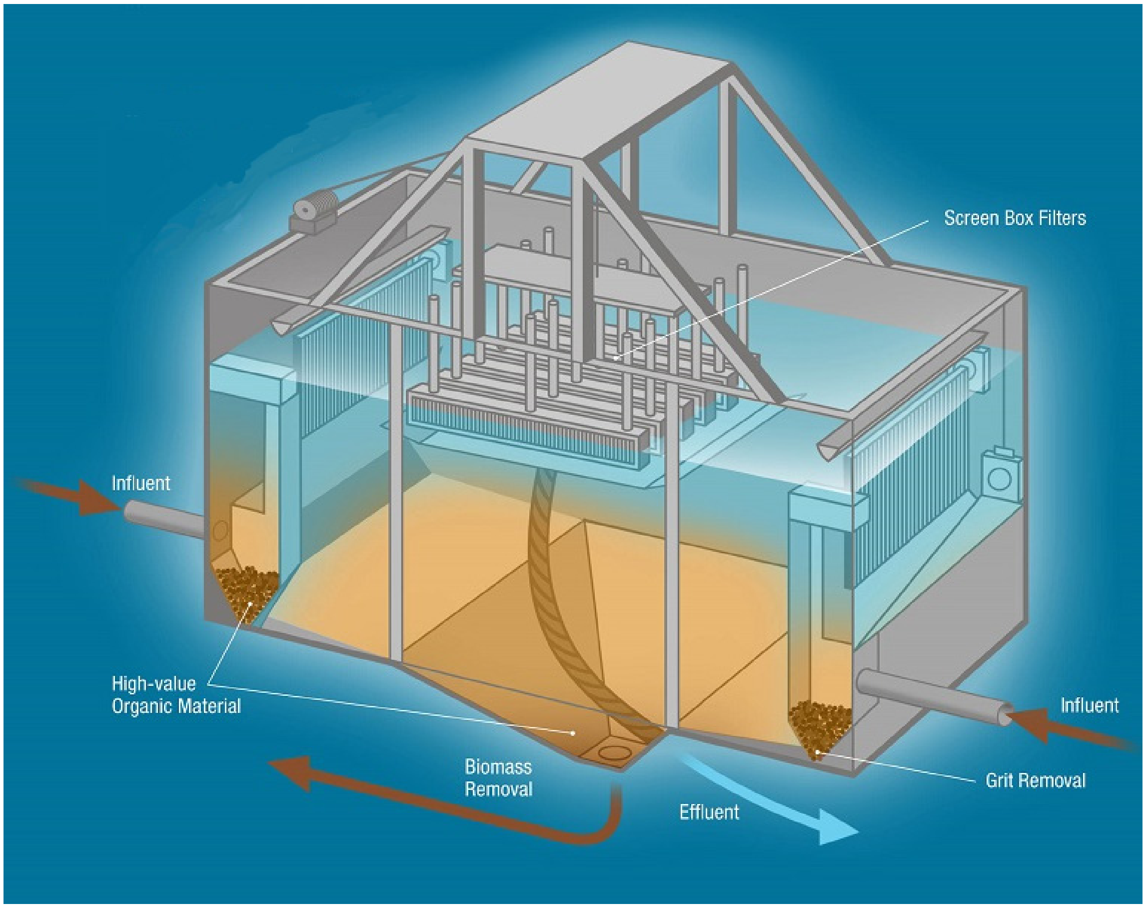


3.1 OH Pilot

The pilot OH unit (shown in Figure 4 and Figure 5) has a capacity up to 24,000 GPD, has two IFSs that each have a grit box and feed trough, a central sludge hopper for sludge removal, and has built-in safety features and alarms with remote monitoring and control that are designed for unattended operations. The unit was installed in close proximity to the headworks of the IAWWTF. Raw sewage was pumped to the pilot from the influent feed channel of the IAWWTF downstream of a 1.5-inch climber screen and upstream of plant process side stream returns from thickeners, anaerobic digesters, belt press, tank drains, and any chemical additions.

Figure 4. OH Pilot Unit

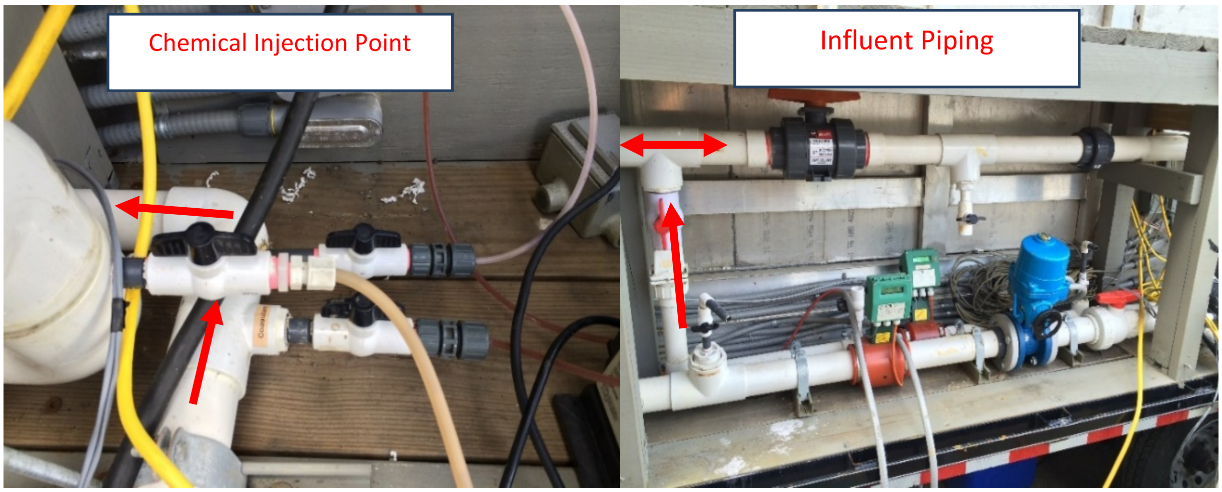
Figure 5. OH Pilot Diagram



Raw sewage was pumped to the pilot from the influent feed channel of the IAWWTF at 80 gallons per minute (GPM). The pump was positioned so the intake was in the center of the liquid depth to get a cross section of the wastewater. This centrifugal pump can pass a 2-inch solid. Coagulant and polymer were injected prior to the wastewater entering the pilot's IFS, as seen in Figure 6. The chemical dosing was to be paced by organic content as measured by the UVAS (ultraviolet absorption spectrometer), but it proved difficult to keep the UVAS probe clean resulting in inconsistent operation. In a full-scale installation, the probe would be mounted inline to prevent FOG and stray rags from building up on the probe. The operation of the chemical feed pumps was set to flow-paced dosing.

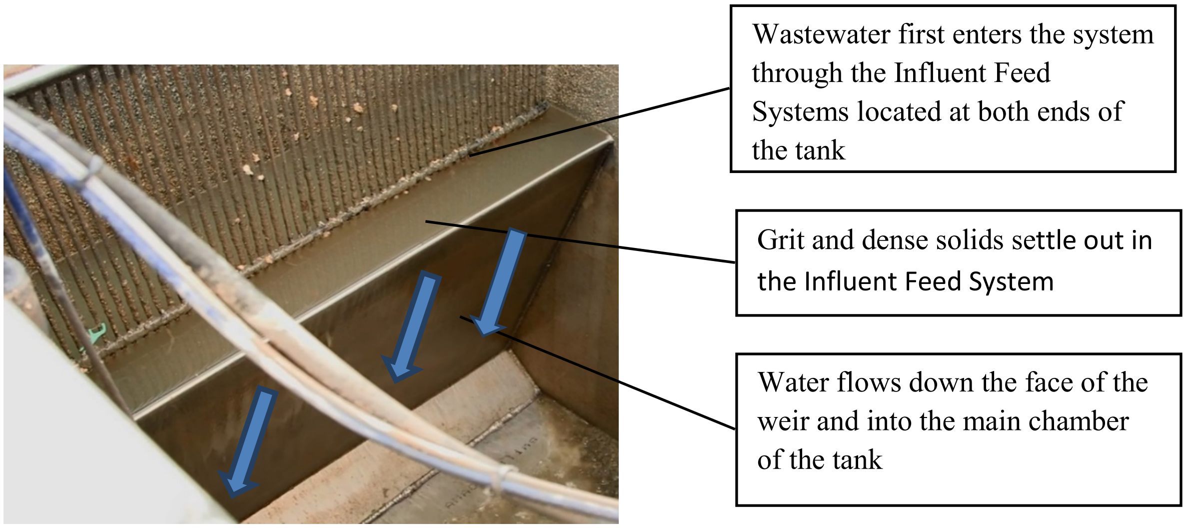
There is approximately 15 to 16 seconds of hydraulic retention time between the chemical injection point and the pilot unit. The OH pilot has no dedicated mixing mechanism due to the limitations of physical scale. However, the liquid does flow through three elbows before reaching the pilot via the IFS. A full-scale system would have a high velocity mixing zone in each grit box and a longer hydraulic retention time resulting in lower chemical dosing rates and, possibly, higher organic and solids removal rates.

Figure 6. Chemical Feed System



The dosed wastewater enters the pilot unit through the two influent feed systems located at opposite ends of the OH tank. Each IFS has a grit box and influent weir. The rise rate in the grit box is 0.14 FPS (feet per second) and the U.S. Environmental Protection Agency's (EPA) stated settling rate for 50-mesh solids (grit) is 0.16 FPS. The liquid then takes a 90-degree turn horizontally into the feed trough. The rise rate in the feed trough is 0.016 FPS and the U.S. Environmental Protection Agency (EPA) settling rate for 100-mesh solids is 0.042 FPS. The low rise rate allows the grit and heavier solids to settle in the IFS. The IFS serves to provide scouring of the bottom of the tank's main chamber and moves the light fluffy solids to the center hopper. The IFS is illustrated in Figure 7.

Figure 7. Influent Feed System and Weir



The main chamber of the OH has a surface area of 48 square feet (4 ft × 12 ft), an operating volume of 790 gallons with a high water level of 5.0 ft and a low water level of 2.8 ft.

For this demonstration, the OH pilot ran in a modified "Peak Day/Peak Hourly" mode with the influent pump starting at the low water level and pumping continuously until the high water level was reached and the pump shut off. The discharge flow rate and high water level were kept the same because the high water level is only 2.2-ft away from the low water level versus 7 ft in a full-scale unit. The pump ran continuously because the pilot does not have "time of day" programming incorporated, which would automatically adjust the pumping rate based on the flow into the facility. In a full-scale system, with influent flows into the plant being less than the peak hourly, the flow to the OH would cycle on and off as the liquid level in the Influent Pump Station wet well reached the "pump on" elevation and then off when the volume in the wet well lowered to the "pump off" elevation. To compensate for not having intermittent fill and settle periods associated with normal operations, a 35-minute settling period was incorporated. Simulations using "average day" diurnal flow patterns, influent pumps sized for peak hourly flow, and an influent wet well sized to satisfy less than seven pump starts an hour (low flow conditions) resulted in the pumps being off for 40+ minutes out of every hour.

Normal OH operations include an automatic scum cycle, wherein the pilot unit liquid level is raised to 5.25 ft with the scum trough weir elevation at 5.17 ft. These pilot unit elevations would be 6.5-ft higher in a full-scale system. The scum valve opens when the liquid reaches 5.25 ft, and the influent pump runs for a field-set fixed time to ensure scum, floatables, and FOG are removed through the trough. The trash is screened from the FOG and sent to the landfill; if the digestible FOG concentration is enough to warrant being directed to the digester, then that process can be facilitated.

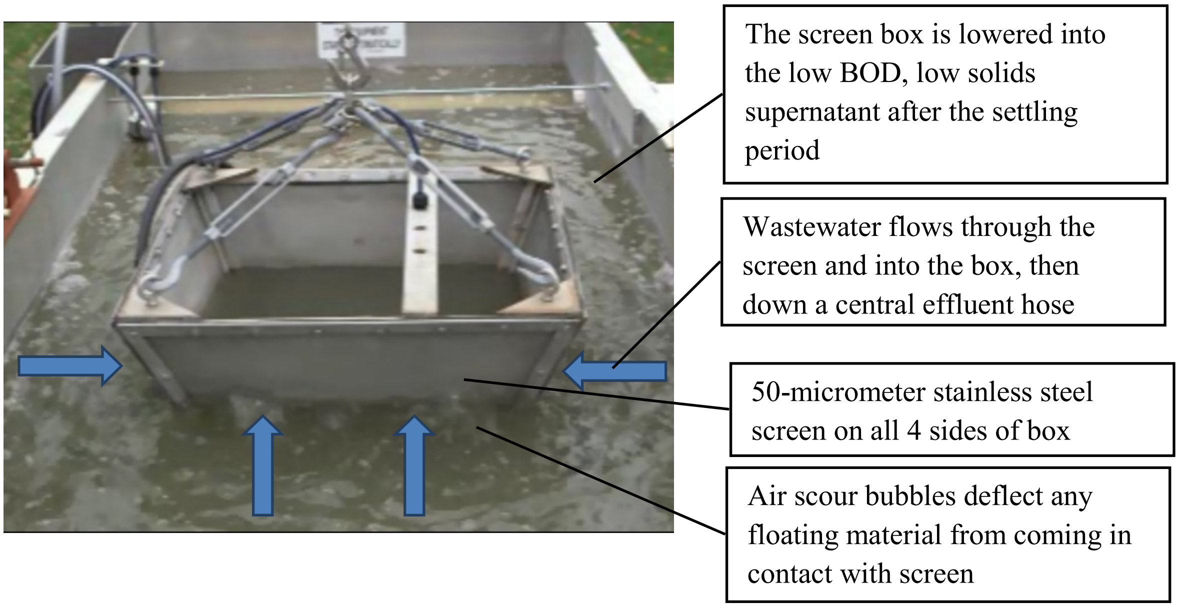
Minimal scum or floatables were observed in the pilot tank during the demonstration, so scum cycles were manually activated at the operator's discretion. The lack of scum and floatables may have been due to the position of the pump at the mid-liquid level of the influent channel.

The screen box has no issue with FOG, as the screen is below the liquid surface and an air scour on the screen box deflects floatables, FOG, and fibers to prevent such contents from coming in contact and blinding the screen in any way.

The end of the settle period starts the decant cycle. The OH Control System lowers the screened decanter (i.e., screen box) into the liquid. When the appropriate screen surface area is in contact with the liquid, the air scour is activated and then the effluent modulating valve opens until the effluent flow reaches the target flow rate. The screen loading rate for this demonstration was run at the normal design loading rate of 4 GPM/SF resulting in a velocity of 0.009 FPS at the screen/liquid interface. The low velocity, air scour, and operation in a low solids/ organics region of the tank allow the 50-micrometer screen to operate without fouling. The screen descends at the same rate as the liquid level to maintain the desired screen surface area in contact with the liquid.

When the low water level is reached, the effluent modulating valve is closed. When the valve is closed, the screen box is lifted quickly, causing the screened liquid in the screen box to back flush the screen at a much higher velocity than it entered, and thus cleaning the screen each cycle. The photo of the decanter in Figure 8 does not reflect the size or shape of a full-scale screen box, as it is for pilot testing purposes only.

Figure 8. Decanter Screen Box



A deflector plate is located below the screen box to prevent the vertical currents caused by the air scour from disturbing the light settled sludge. For this demonstration, the low water level was 2.8 ft. In a full-scale system, the low water level is projected to be greater than 5 ft. It is typical, based on accepted design standards, for the tank depth to be 14 feet or deeper. The increased operating depth and size of the full-scale OH reactor /tank provides flexibility in cycles not allowed in this smaller OH pilot tank, while allowing for the decanter to work further away from the sludge blanket where removal rates are indicated to be higher. These two factors have the potential to increase the removal rates of TSS, chemical oxygen demand (COD), and total phosphorus (TP) in a full-scale system, or result in lower chemical dosing rates to maintain the same removal rates as the pilot.

The concentrations of various constituents captured in the OH are managed by removing a calculated amount at a specified time interval. Based on the influent/effluent concentrations of this demonstration, 20 gallons of sludge were to be removed at the end of each settling period to maintain consistent removal rates and internal inventory of captured constituents. The time to open and close the actuated sludge valve allowed an estimated 60 gallons of sludge to exit at a minimum $\pm$10 gallons. This aspect of the pilot's operation was addressed by removing an estimated 60-80 gallons of sludge every three to four cycles to maintain a stable concentration of TSS, COD, TP, and residual chemicals in the sludge blanket. The captured grit and medium density solids in the feed troughs and grit boxes were removed every 10 cycles.

The sludge wasting process was optimized based on the COD concentration of the hopper sludge and the volume of sludge removed from the pilot unit. Onsite process testing to establish the COD concentration of the hopper sludge was performed using a Sludge Judge to collect the samples from the bottom of the hopper. The goal was to provide a stable COD load/concentration and residual coagulant/polymer content in the OH tank.

All of the pilot unit's operating parameters can be adjusted through a human machine interface (HMI) on the control panel. Such variables include, but are not limited to:

- Settle time.
- Chemical dosing rate.
- Pump rate.
- Screened decanter position.
- Screen loading rate.
- Target Flow Rate (Effluent).
- Sludge and grit withdrawal time and frequency.

Composite samplers were activated by the pilot's control system to collect influent samples when the influent pump was on and effluent samples when flow was detected in the effluent. The sampling pump ran at a fixed speed during each sampling period thus collecting the same volume for each cycle. The OH influent and effluent flow rates (GPM) were fixed or remained the same for each cycle throughout the day.

Twenty-four hour composite samples of the OH pilot influent, OH pilot effluent, OH pilot sludge (900-gallon holding tank, see Figure 3), and IAWWTF primary clarifier effluent were collected multiple times per week and analyzed by a third-party laboratory for:

- Biochemical Oxygen Demand, 5-day (BOD_5).
- Soluble Biochemical Oxygen Demand, 5-day ($SBOD_5$).
- Chemical Oxygen Demand (COD).
- Total Suspended Solids (TSS).
- Volatile Suspended Solids (VSS).
- Total Phosphorus (TP).
- Total Kjeldahl Nitrogen (TKN).

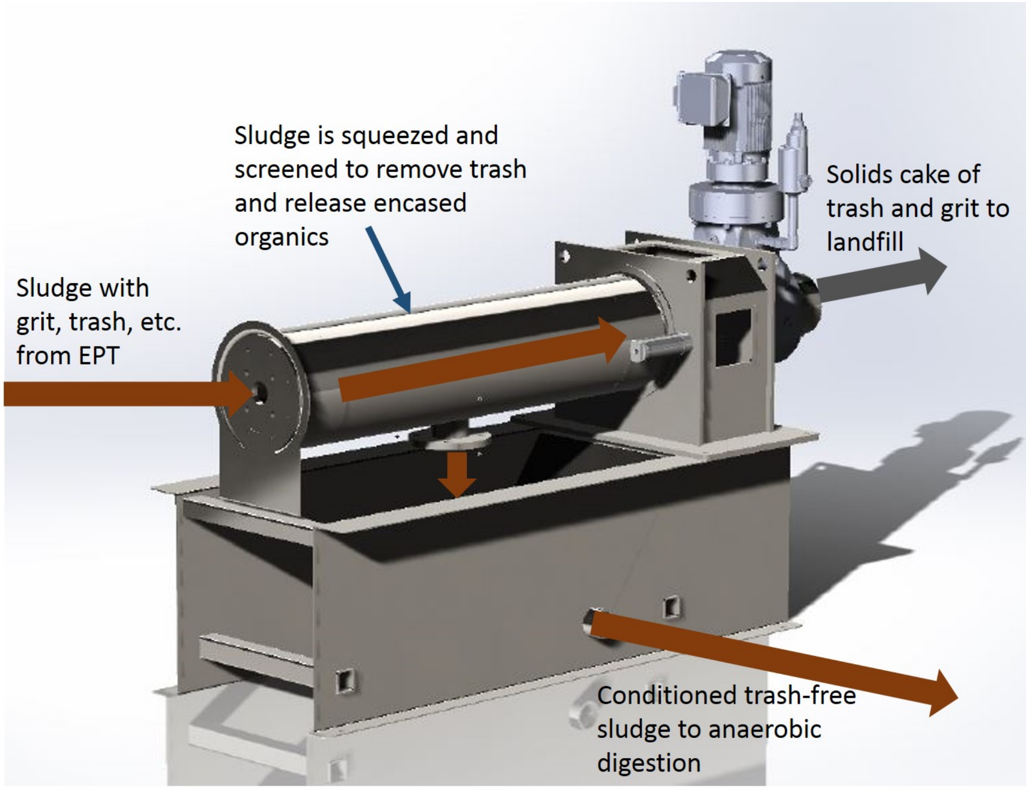
3.2 Sludge Cleaning and Enhancement Process (SCP) Pilot

The SCP pilot is an enclosed trailer-mounted sludge processing technology developed by ClearCove that cleans and conditions the captured OH sludge for higher biogas generation via anaerobic digestion. The SCP unit removes trash and the large solids from the OH sludge while shearing and squeezing the encased organics into the liquid sludge, and limiting the particle size to provide greater surface area.

Sludge was pumped from the 900-gallon holcding tank at 15 GPM into the SCP unit. The sludge enters in the center of a perforated circular screen flowing horizontally with the liquid sludge exiting at 90^{o} to the direction of flow through the screen. Figure 9 and Figure 10 show the flow of sludge through the SCP unit.

Figure 9. SCP Pilot Unit

Figure 10. SCP Flow Diagram



The solids greater than the size of the screen openings remain inside the screen. As the influent pressure increases due to the solids blocking the screen openings, a pressure transducer activates the auger variable frequency drive (VFD) and the auger rotates to clear the openings. The fouling solids are moved toward a backpressure plate to form a solids cake. The solids cake is composed primarily of hair, grit, plastics and other trash. The cake, which contains the inorganic solids removed from the sludge, falls into a bin for disposal. At full scale, this cake would be bagged to control odors and sent to the landfill because of its low moisture content. The cake will not be washed as to prevent the capture fibers and small trash particles from re-entering the waste stream.

The “conditioned” sludge flows from the SCP to a sump where it is pumped into a 300-gallon tank (Figure 3) for thickening prior to being transported to the digester pilots. The SCP was run as needed each day to condition the sludge fed to the pilot digesters and BMP.

The OH and SCP, in conjunction with one another, replace conventional headworks and primary treatment. The OH and SCP, however, can be operated in applications independently of one another. Since the study was completed, a Rotary Drum Thickener has been added to the SCP solution in anticipation of replacing conventional gravity thickeners to thicken primary sludge.

3.3 Pilot Digesters

In March 2014, four 500-gallon pilot-scale digesters were installed at the IAWWTF. However, the operation of these digesters was discontinued due to limited materials handling capabilities. In June 2014, four 350-gallon, pilot-scale digesters were installed in the first floor of the Digester Building at the IAWWTF, as shown in Figure 11. This area is designated as Class 1/Division 1 space, with all equipment and instrumentation to be intrinsically safe, or it is located outside this space. The digesters were configured to operate with 100-gallons of active volume. Each pilot digester had the following components, which will be referenced in the system description:

- 350-gallon digester tank.
- 100-gallon feed tank.
- Air-operated double diaphragm feed pump.
- Air-operated double diaphragm heating and mixing pump.
- Tubular heat exchanger, 15.7 square-foot surface area.
- Temperature probe.
- Manometer.
- Differential pressure biogas flow meter.

Figure 11. Pilot Digesters

Each digester was paired with a dedicated feed tank that held its specific sludge as shown in Figure 12. Each pair's feed pump constantly pumped the feed sludge in a recirculation loop running from the feed tank to the digester and back to the feed tank. This step provided gentle mixing of the feed tanks and prevented a scum layer from forming, which could eventually lead to the fouling of the feed pump, as explained further in Section 4.

Figure 12. Digester Feed Tanks

One feed tank is dedicated to each digester.

Each feed tank fed the digester its specific sludge. The sludge types used in the experiment were as follows:

- **Digester 1 IAWWTF Thickened Sludge** – same sludge the IAWWTF feeds its full-scale digester, a combination of IAWWTF primary and secondary sludge collected from the full-scale sludge thickening tank. This digester was the control, fed at the same rate as the full-scale digester at 50 lb VS/day/kcf digester volume.
- **Digester 2 IAWWTF Primary Sludge** – sludge from the IAWWTF conventional primary clarifiers. The sludge was filtered to remove gross inorganics to prevent clogging in the feeding and circulation process. Fed at the same rate as the full scale digester.
- **Digester 3 ClearCove OH Sludge –** sludge from the OH pilot after being conditioned by the SCP. Fed at the same rate as the full scale digester.
- **Digester 4 ClearCove OH Sludge** – same sludge as Digester 3, but fed at twice the daily pounds of volatile solids (VS) as Digester 3.

Section 5.4 provides more detail on the pilot digesters' feed and loading rates.

The IAWWTF Thickened Sludge and IAWWTF Primary Sludge both required screening prior to being loaded into the feed tanks due to large inorganics, such as rags and grit, which remained in the sludge. This screening activity likely enhanced the biogas generation for both of IAWWTF sludges. In Ithaca's existing full-scale operation, these inorganics are not adequately screened out and eventually make their way into the digester. The IAWWTF Primary Sludge also required thickening prior to it being loaded into the feed tanks due to it being extremely diluted from the facility's degritting process.

A solenoid valve in the feed recirculation loop redirected the flow to the digester as part of the feeding mechanism. The solenoid valves, set on timers, controlled the duration during which they were open and the time between openings. The timer settings were determined based on measurements of TS and VS for each feed sludge. The measurements were performed multiple times per week to ensure the targeted amount of VS, as measured in pounds per day, were fed to the digesters. Feed slug volumes were measured and samples were collected on a daily basis to determine the actual loading rates.

Each digester had a dedicated heating and mixing double diaphragm pump. The digester sludge was pumped from the bottom of the digester to the digester's dedicated heat exchanger. The heat exchangers were tied into the hot water supply of the IAWWTF to maintain a digester sludge temperature between 95-98 degrees Fahrenheit. After moving through the heat exchanger the sludge was pumped back to the digesters. The sludge was re-injected through four internal nozzles that provided mixing within the digesters.

The liquid level of the digesters was controlled by an overflow gooseneck set at the appropriate height to maintain 100 gallons. As feed slugs of fresh material were delivered into the tank, the corresponding amount would overflow from the gooseneck.

Manometers were tied into the gas lines of each digester to monitor internal pressure. The manometers, which indicate when there is a vacuum within the digester, allowed the operations team to quickly notice if there was a leak in the system.

Biogas generated in the digesters was vented through differential pressure flow meters located outside of the digester room. The biogas flow meters, as well as readings from the temperature probes, were recorded every 10 seconds to a data card in a programmable logic controller (PLC) outside of the digester room.

The pH of the digesters and feed tank was tested twice daily to assure a pH range of 6.8-7.1. Digester carbon dioxide (CO_2) gas was also checked daily from the digester's biogas sampling line with a Fyrite gas analyzer. Total solids and volatile solids analyses on the feed sludge and digester effluent were also performed on a routine basis each week to determine the loading rate and destruction rate of each digester.

Sludge samples were collected from the feed tanks and digesters multiple times each week and sent to a third-party laboratory to test the following parameters:

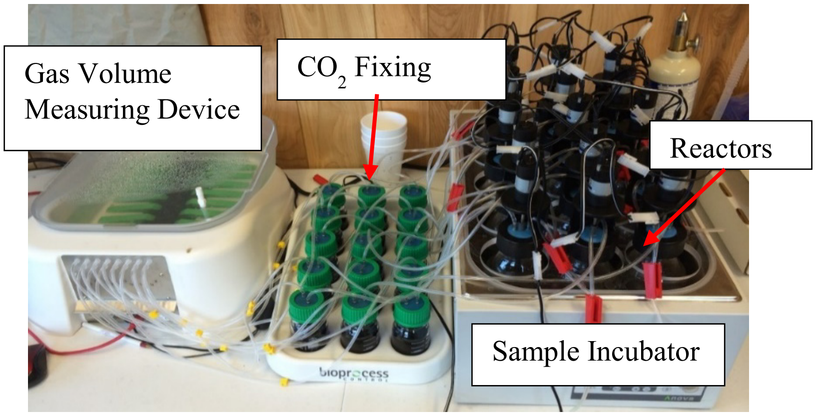
- COD.
- TS.
- VS.
- Ammonia.
- Orthophosphate.

3.4 Biochemical Methane Potential Unit

Biochemical methane potential (BMP) testing was performed simultaneously with the digester pilots. The BMP was measured using an Automatic Methane Potential Test System (AMPTS II) from Bioprocess Controls. The purpose of the BMP testing was to validate and corroborate the data generated by the digester pilot. As shown in Figure 13, the BMP equipment consisted of:

- Sample Incubator.
- Fifteen 640-mL Reactors.
- CO_2 Fixing Unit.
- Methane Volume Measuring Device.

Figure 13. Bioprocess Controls AMPTS II Equipment



The BMP system allows for fifteen 640-mL reactors to be run at the same time. A calculated amount of substrate sludge and inoculum sludge was placed into each reactor based on VS analysis performed on the sludge prior to the test and desired inoculum/substrate ratio. The sample incubator is a water bath which holds a set temperature; in this experiment, the desired temperature is 98^{o} Fahrenheit. All 15 reactors sat in the sample incubator bath together, ensuring that they were all kept at the same stable temperature.

Biogas that was generated in the reactors flowed through tubes and into the CO_2 stripping unit which removed CO_2 from the gas. From the stripping unit, the methane gas flowed into the methane volume measuring device. It is important to note that the gas volume measuring device used with the BMP equipment was different from the differential pressure biogas flowmeters utilized for the digester pilots. The Bioprocess Controls gas volume measuring device uses submerged paddles that float upwards when a known volume of gas builds up underneath. When the paddle floats up, it triggers a counter that registers the volume of gas that has been incrementally generated.

The gas measuring device was linked directly to a dedicated computer that recorded the biogas generation of each individual reactor in real time. Tests would typically run from 1.5 to 2 weeks, continuing until the measured methane generation rate of each reactor leveled off. After the test was completed, the reactors would be cleaned and another test would begin with fresh substrate and inoculum.

4 Start-up and Optimization

4.1 Start-up and Optimization of OH and SCP Pilot Units

4.1.1 Chemical Optimization of OH Pilot

Chemical selection and dosage optimization were performed to determine which chemicals and dosage rates (milligrams per liter [mg/L]) would offer the best economic return based on energy reduction and energy generation. Three coagulants were tested: ferric chloride ($FeCl_3$), PCH 180 (polyaluminum chloride), and Slack Plus (aluminum chloride hydroxide sulfate- based coagulant). Each coagulant was tested at 30 mg/L, and all in combination with 1.0 mg/L of anionic polymer. Two duplicate jar tests were done. The average results of the jar test (Figure 14 and Table 1) show a similar performance from each of the coagulants. The IAWWTF uses $FeCl_3$ in its full-scale operation, so it is familiar with the product. A Hach DR890 colorimeter was used onsite to determine the COD and turbidity measurements. Used for the optimization period, this returned measurements in two hours rather than waiting for the 10-day turnaround period of a third-party laboratory.

Figure 14. Jar Testing – COD and Turbidity - Average

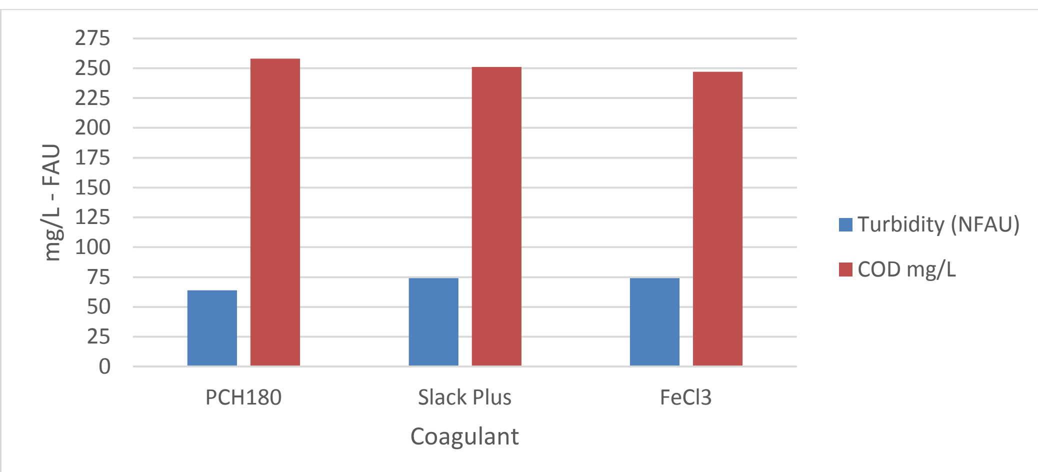
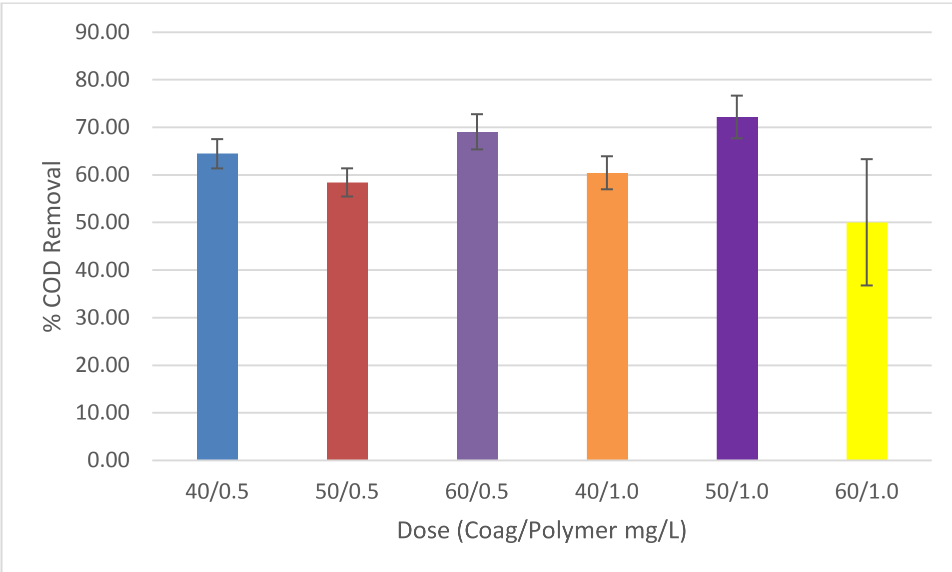


Table 1. Jar Testing – COD and Turbidity

	PCH180	Slack Plus	FeCl3
Turbidity (NFAU)	64	74	74
COD (mg/L)	258	251	247

Figure 15. Coagulant/Polymer Dosing Combinations (Average of multiple results)

Error bars represent 95% confidence intervals.

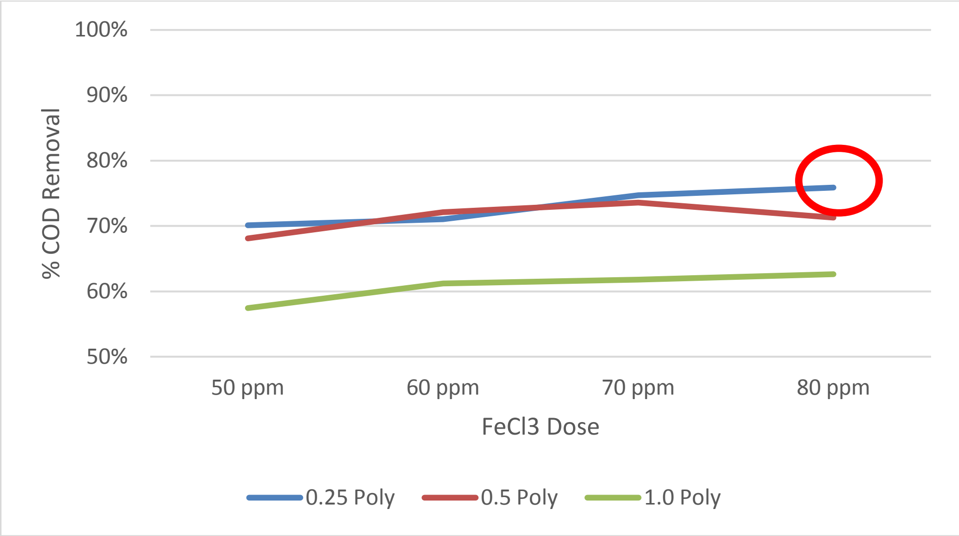


The next step was to optimize the dosage of $FeCl_3$ and polymer. Six coagulant and polymer combinations were tested through the operation of the OH pilot. The COD removal rates, shown in Figure 15, reflect the superior COD removal rate achieved through the 50 mg/L $FeCl_{3,}$ 1.0 mg/L anionic polymer combination.

After the 50/1.0 dosage combination was selected, additional jar testing was performed to determine the value of a higher $FeCl_3$ dose. The results of this jar testing are shown in Figure 16, and indicate that the dosage combination of 80 mg/L $FeCl_3$ and 0.25 mg/L anionic polymer provided the best results, as highlighted by the point circled in red. An economic analysis was performed to ensure that the dosing rates would not increase the chemical costs of the IAWWTF.

Figure 16. Jar Testing COD Removal

The red circle indicates the highest removal rate achieved by the jar test at the dose of 80 mg/L of $FeCl_3$ and 0.25 mg/L anionic polymer.



In addition to the dosage combination testing, a single test was run of the OH pilot with no chemical addition. Without chemical addition, the OH achieved 46% COD removal. The technology has been piloted and tested with no chemical at several other facilities including Niskayuna Wastewater Treatment Plant, Avon Wastewater Treatment plant, and Macedon Wastewater Treatment Plant.

Over the course of the project, 24-hour composite samples were collected under both the 50/1.0 and 80/0.25 dosage combinations.

4.1.2 OH Pilot Operating Strategy Refinement

The OH is a gravity settling concentrating device that retains the captured organics, nutrients, and solids until they are removed via sludge withdrawal. Prior OH pilot testing showed that a higher COD removal rate was achieved when the settled solids/sludge were removed every three to five cycles versus every cycle. The same pilot testing also showed reduced COD removal rates when the sludge was withdrawn every eight to 12 cycles. A test was established to compare two sludge wasting methodologies:

- **Set Point 1:** performed a sludge scour every cycle to clean and empty the entire tank so next cycle would begin with an empty tank. This process eliminates the organic content from the previous cycle from influencing the COD removal rate.

- **Set Point 2:** did not empty the tank but removed approximately 60 gallons of sludge at the end of the settle cycle for each cycle. The volume of sludge to withdraw was estimated because the colleges were out of session so the organic content was decreasing.

Both Set Points were tested with Coagulant + Polymer dosing rates of 40:0.5, 50:0.5, 60:0.5, 40:1, 50:1, and 60:1. The average removal rate for Set Point 1 was 59%; and, Set Point 2 was 63%. For this reason, Set Point 2 was run for this demonstration.

4.1.3 OH Pilot Influent Start-up and Optimization

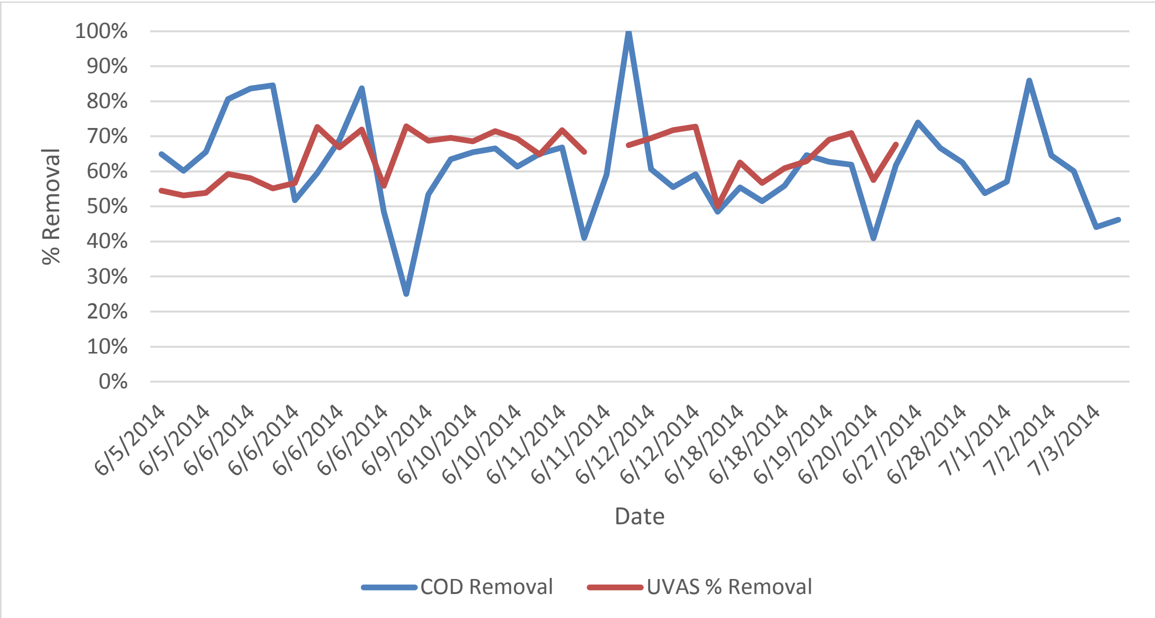
The OH was operated 24 hours per day, seven days per week during this six-month demonstration, with minor interruptions to accommodate plant access needs. An influent pump delivered 80 GPM of raw sewage to the OH pilot and was positioned in the influent channel flow splitter box, so it received all flows entering the headworks, including plant drains, process tank drains, septage hauler loads, and the wastewater after it passed through a 1.5-inch mechanically cleaned bar rack. The pump was suspended in the middle of the liquid depth to receive a cross-section of the wastewater constituents.

The UVAS sensor did not provide consistent operation, and thus was abandoned. In prior pilots, the UVAS was successfully used to measure the COD concentration at different levels in the OH tank, the influent and effluent COD in real time, and to control the chemical dosing rate based on organics versus flow. The influent sensor was suspended in IAWWTF's influent channel. The probe and cable collected rags, trash, baby wipes, and FOG. The discharge of liquid haulers just upstream caused the probe to routinely be covered in grease, thus requiring the probe to be disconnected and manually degreased using chemical cleaning products. Weekly cleaning was not adequate and due to operator health and safety concerns, the use of the sensor was terminated.

Issues with the UVAS probe created the need to explore the use and accuracy of other technologies used in wastewater treatment to measure real-time wastewater characteristics. The COD Reactor more closely matched the UVAS readings, as shown in Figure 17, and was used for process monitoring and testing of sludge. Chemical dosing was flow paced versus organic concentration paced due to the inconsistent operations of the UVAS.

Figure 17. COD and UVAS Removal Measurements

For more detail on the OH pilot start-up and optimization data, see Appendix A.



4.1.4 OH Effluent Start-up and Optimization

The screen box, or screened decanter, was operated at the standard screen loading rate of 4 GPM/SF, which produces a velocity of 0.009 FPS at the screen/liquid interface (where the screen and liquid come in contact). The OH control system allows the operator to enter an effluent flow rate (24 GPM) and a screen loading rate (4 GPM/SF). The controller then adjusts the position of the screen box to provide the required screen surface area in contact with the liquid. The controls lower the screen box at the same rate as the liquid level in the OH is lowered to maintain the same contact surface area throughout the decanting.

The effluent from the OH was returned to the influent channel downstream of the influent pump.

4.1.5 OH Sludge Start-up and Optimization

The depth of the settled sludge on the 4 ft × 4 ft flat sections of the tank bottom and in the hopper were measured daily, from August 8 to October 2, with a Sludge Judge. There are no mechanical components, such as flights and chains, in the OH tank to move the sludge to the center sludge hopper. The movement of the light fluffy sludge on the bottom of the tank to the hopper was achieved by the influent liquid scouring the tank bottom into the central hopper. The OH pilot unit has a tank 12-ft long and 4-ft wide, with a 4 ft-square hopper with side slopes of 60 degrees. The flats are 4 ft × 4 ft on each side of the center hopper. During this time frame, the tank was not drained, the influent feed trough weir elevation was fixed at 3.1 ft, and the low water level was set at 2.8 ft. There was no floating sludge observed during the demonstration, which indicated that the solids were being moved out of the OH tank in adequate time. The sludge depth in the flat sections of the tank bottom averaged 2 inches with a maximum of 10 inches and a minimum of 0 inches. The hopper sludge measured on average 18 inches with a maximum of 40 inches and a minimum of 6 inches.

One of the most challenging aspects of the pilot was the sludge processing and management. The ability of the OH to capture organics and solids had been proven in prior pilots. The capability to process (clean and thicken) the light highly organic matter, as well as all the other solids greater than 50 micrometers, had not been realized prior to this demonstration. The goal now was not only to capture but to retain these fine light organics for delivery to the pilot digesters and the BMP unit.

The initial volume of sludge required to feed the 350-gallon digesters was overwhelming. The early stages (April-July) of feeding the pilot digesters involved manually filling 5-gallon pails, allowing them to settle, decanting the supernatant, and combining sludge samples until approximately 20 five-gallon pails of 1-2% solids were obtained. As the SCP was not onsite until July, the sludge in these 20 pails was run through a strainer after suctioning by the pilot digester feed tank recirculation pump.

The sludge thickening process was refined by the addition of a 900-gallon surge tank piped to the OH sludge hopper. The estimated volume of sludge delivered to the 900-gallon tank varied with the number of cycles completed each day from 17 to 21, averaging 19 cycles per day. Sludge was removed from the main hopper of the tank every fourth cycle, and sludge was removed from the influent feed system (IFS) every 10th cycle. On average, 285 gallons of sludge from the hopper and 171 gallons of sludge from the IFS were delivered to the 900-gallon holding tank each day.

The OH solids processing system equipment was introduced to the pilot in late July 2014. This system was constructed and optimized over a three-week period before continuous operation from August 15, 2014 through the remainder of the pilot study. The optimized OH sludge handling process consisted of:

- Gravity feed from the OH sludge hopper and both IFS systems entering into a 900-gallon flat bottom holding tank with an operating volume of 780 gallons. The IFS and hopper sludge lines were equipped with actuated valves to allow for the automatic discharge of the sludge as programmed into the automated control system. The 3-inch actuated hopper sludge valve required a minimum of 22 seconds to open and close, resulting in a minimum discharge of approximately 60 gallons. The total volume of sludge added to the 900-gallon tank each day was measured by noting the change in the sludge level in the graduated tank.
- A mixing/transfer submersible pump installed in the 900-gallon holding tank that mixed the tank when not discharging to the SCP. When the sludge was uniformly mixed, the feed valve connecting the submersible pump to the SCP was opened and the recirculation valve closed. Samples of this mixed sludge were used as a daily composite sample as solids would plug a composite sampler.
- The SCP feed entering the center of a perforated circular screen, whereby liquid and solids less than 1/16 inch passed through and larger solids and hair were captured and compressed to form a dry sludge cake for disposal. The SCP screened sludge discharged to a feed trough.
- The SCP sludge next being pumped into a 300-gallon coned tank.
- The 300-gallon coned tank having overflow piped back to the influent channel and a valved hose at the base of the cone for withdrawal of the sludge. The overflow reduced the usable volume of this tank to 280 gallons.

4.1.6 Sludge Cleaning and Enhancement Process (SCP) Start-up

The submersible pump delivered sludge from the 900-gallon tank to the SCP at 15 GPM. The sludge enters in the center of a perforated circular screen flowing horizontally with the liquid exiting at 90 degrees to the direction of flow through the screen. The solids greater than the size of the screen openings remain inside the screen. As the influent pressure increases due to the solids blocking the screen openings, a pressure transducer activates the auger VFD and it rotates to clear the openings. The fouling solids are moved toward a backpressure plate to form a solids cake. The solids cake is composed primarily of hair, grit, plastics, and other trash and will be disposed of by incineration or landfill.

No coagulant or polymer was added to the sludge prior to the SCP other than those chemicals added to the raw sewage in the influent pipe prior to entering the OH.

The conditioned sludge pressate exited the SCP flow by gravity into a small low profile tub that served as a wet well. The transfer pump in this wet well had a capacity of 15 GPM and delivered the post-SCP sludge to a 300-gallon coned tank. The 15-GPM capacity of this transfer pump was the limiting factor in the SCP feed rate. The SCP was fed at rates greater than 100 GPM when cleaning (removing solids greater than 1/16 inch) sludge onsite at a different location.

There was no sludge thickener, such as a gravity belt or rotary drum. There were no additional chemicals added to thicken the OH hopper, grit, and IFS sludge. The post-SCP sludge was allowed to settle for approximately 45 minutes, resulting in a 1.44% solids sludge. This post-SCP sludge was then delivered to the pilot digester and BMP equipment as needed. At full scale, the SCP would include a thickener component, such as a gravity belt or rotary drum and polymer addition, which would allow for the sludge to be brought to 3-5% solids prior to feeding to the digester.

4.2 Pilot Digester Start-up and Optimization

A number of factors were optimized for the pilot digesters to operate in a steady state, including:

- Feeding.
- Mixing.
- Temperature control.
- Materials management.
- Thickening of primary and OH sludge.
- Straining of thickened and primary sludge.

Originally, four 500-gallon tanks with an operating volume of 400 gallons were installed to act as the pilot digesters. These digesters were to be fed constantly by low flow peristaltic pumps. Due to the small volumes of feed material that needed to be moved at the constant rate, small volume pumps and small diameter hoses were originally installed. These pumps and hoses encountered plugging issues due to the solids in the sludge and prevented the digesters from being adequately fed. To mitigate this problem, double 0.5-inch diaphragm pumps were installed for the feed pumps with 0.5-inch hoses. Instead of constantly pumping sludge to the digester, the double diaphragm pumps sent the feed sludge in a recirculation loop. A solenoid valve was installed in the recirculation loop to divert the sludge to the digester in slugs, as previously described. The double diaphragm pumps reduced the plugging issue but did not eliminate it completely. Eventually, the 0.5-inch pumps were replaced with 1-inch pumps with 1-inch hoses which significantly reduced the instances of plugging in the pumps or lines.

The feeding strategy was to deliver a steady, relatively constant loading of VS from each pilot unit. The sludge was collected from three different locations around the IAWWTF via manual conveyance. The sludge was manually loaded into its designated feed tank through a suction line in the pump recirculation loop. Samples were collected multiple times per week from the feed to sludge for TS and VS analysis to monitor the VS loading to the digesters. The times on the solenoid valves were adjusted based on the TS/VS analysis to deliver the target loading for each digester. Feed tank levels were measured and logged twice per day, once before sludge loading and once after. This step made sure that the feed tanks always had enough feed sludge to feed the digesters overnight while the operations team was not onsite.

A number of operating controls were monitored and recorded on daily log sheets to ensure the steady operation of the pilot digesters. Temperature probes on the digester sludge lines provided real time measurement of the sludge temperature within the digesters. This temperature was checked each day to confirm that the temperature of the digesters remained between 95-98 degrees Fahrenheit. The biogas flow was monitored and recorded in real time on the PLC outside of the digester room as well. On a daily basis,
the operations team checked that the flow meters were registering biogas flow. A manometer was also connected to the biogas line for each digester. These manometers were checked and logged each day to monitor the internal pressure of the digester. If the manometer had a negative internal digester pressure, this was an indicator for a possible leak in the system and allowed the operations team to react accordingly. Using a Fyrite gas analyzer, CO_2 readings were taken by the operations team and logged to indicate the performance of the digesters.

Mixing was also a challenge with the original 500-gallon tanks. Samples out of the gooseneck overflows were showing a high percentage of TS. Upon opening the cover of one pilot digester to investigate, “dead zones” were observed. It was clear that the material within the digester was not moving. To improve the mixing conditions, the 500-gallon digesters were replaced with 350-gallon tanks with 100 gallons of operating volume. The 350-gallon tanks had a cone bottom shape and multiple angled sludge injection nozzles inside to ensure thorough mixing of the contents. Prior to seeding the 350-gallon tanks, water was run through the system to give an indication of the mixing effectiveness of the new configuration.

As the digester heat exchangers were tied into the hot water supply of the IAWWTF, the digester temperature was vulnerable to fluctuations in the plant’s hot water temperature. The hot water temperature was provided by the waste heat of the plant’s microturbines. On occasion, the IAWWTF would have one or two of its four microturbines offline resulting in the plant’s hot water temperature and digester temperature to drop. Initially, the operations team would adjust the heat exchangers to raise the temperature of the digesters. This strategy was flawed and would result in the digester temperature going over the desired range of 95-98 degrees once the microturbines were back in service. The policy became, that in the event of a drop in hot water temperature, adjustments would be made conservatively so as to not overshoot the target temperature.

Converting from the larger tanks with operating volume of 400 gallons to the new tanks with operating volume of 100 gallons significantly improved the material management aspect of the project. All sludge was manually transported from each of the different collection points (i.e., thickened sludge line, primary clarifiers, and pilot OH) to the designated feed tanks. The daily feed volume was reduced and, therefore, the volume of sludge to be transported to the feed tanks was decreased. This step allowed for more time to be spent on thickening the primary and OH sludge further.

The OH sludge was conditioned and "cleaned" through the use of the SCP prior to being fed to the digesters. Both the IAWWTF thickened sludge and IAWWTF primary sludge were found to be polluted with grit, rags and other large plastic materials. To prevent these materials from clogging the pilot digester system, the IAWWTF thickened sludge and primary sludge were run through a 0.5-inch strainer nozzle on the suction lines of the feed pumps when being loaded into their respective feed tanks. The sludge coming from the IAWWTF full-scale digester also had impurities that would clog and foul the double diaphragm pumps and pilot-scale digesters. As a result, when the pilot digesters were seeded, the IAWWTF digester sludge was processed through the SCP to remove large inorganic and nondigestible solids which would damage the system.

The IAWWTF performs degritting on the primary sludge captured in its primary clarifiers. This makes the primary sludge relatively dilute -- typically around 0.5% solids or less. At full scale, this dilute primary sludge would be blended with waste activated sludge (WAS) and sent to the thickener. As the pilot digesters are fed based on pounds of VS per day and not sludge liquid volume, it was necessary to thicken the primary sludge to make the transport to the feed tanks feasible. Two 70-gallon hopper bottom tanks were placed at the primary sludge collection point for thickening. The hopper bottom tanks were filled with primary sludge and left to thicken for an hour, after which point the thickened sludge was drained from the bottom and transported to the digester feed tank.

5 Summary of Operation and Performance

5.1 OH Operation and Performance

5.1.1 Sludge Testing to Compare ClearCove's OH Performance to Conventional Primary Clarifier Performance

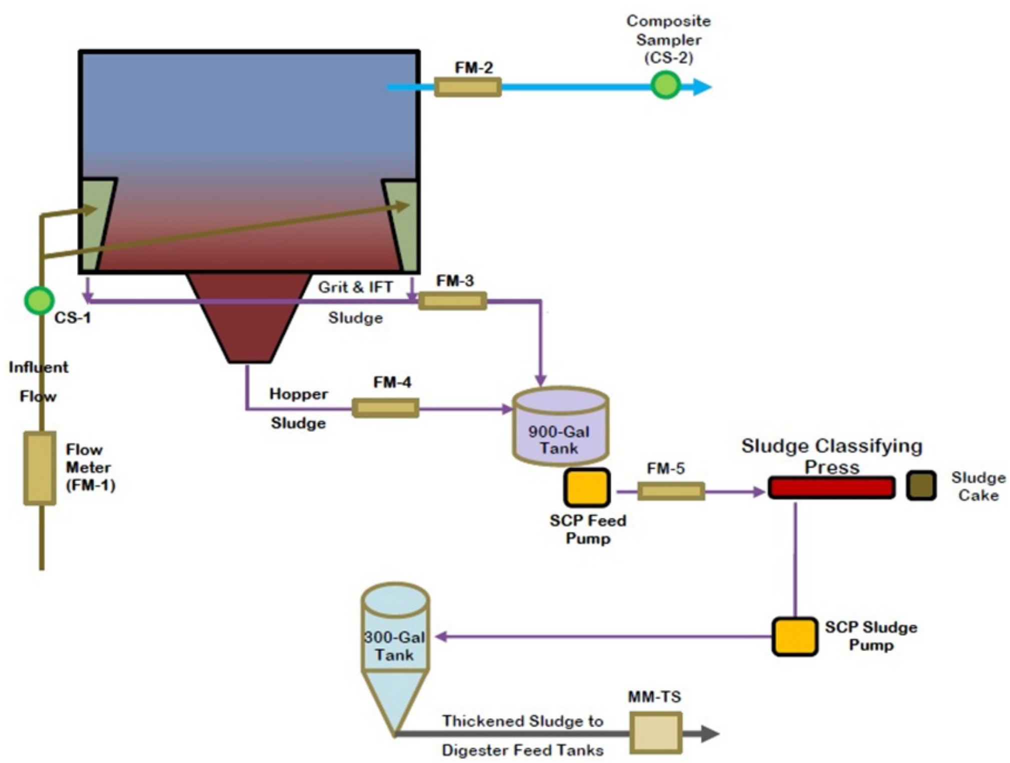
This demonstration compared the removal rates of the ClearCove OH with the average removal rates for a conventional clarifier for $SBOD_5$, BOD_5, COD, TSS, VSS, TKN, and TP.

5.1.2 Composite Sampling of OH

Twenty-four hour composite samples were taken of the OH influent, OH effluent, and OH sludge. A portion of each sample was analyzed for specified parameters by a certified laboratory and by ClearCove for internal process control. The location of the OH and the composite sampler locations are shown in the partial process schematic Figure 18.

Figure 18. Composite Sampler Schematic

Influent composite sampler location (CS-1); effluent composite sampler location (CS-2); 900-gallon tank served as a composite sample of the OH sludge.



5.1.3 IAWWTF Raw Influent

IAWWTF influent samples are taken prior to where side streams from its secondary digester, belt filter press, and thickener are introduced into the wastewater. Consequently, these side streams were not captured and their constituents not measured. This process resulted in a high occurrence of seemingly negative removal rates by IAWWTF primary clarifiers across most of the parameters tested.

The IAWWTF and OH influent raw sewage characteristics during this demonstration are presented in Figure 19. The average is shown numerically in the center of the parameter, and the error bar illustrates the range between the minimum and maximum concentrations in the sampling.

Figure 20 displays the influent characteristics from the historical data of the IAWWTF from the time period of March 2012 - September 2014.

Figure 19. Influent Characteristics for Demonstration Period

Error bars represent range from maximum and minimum values in data set

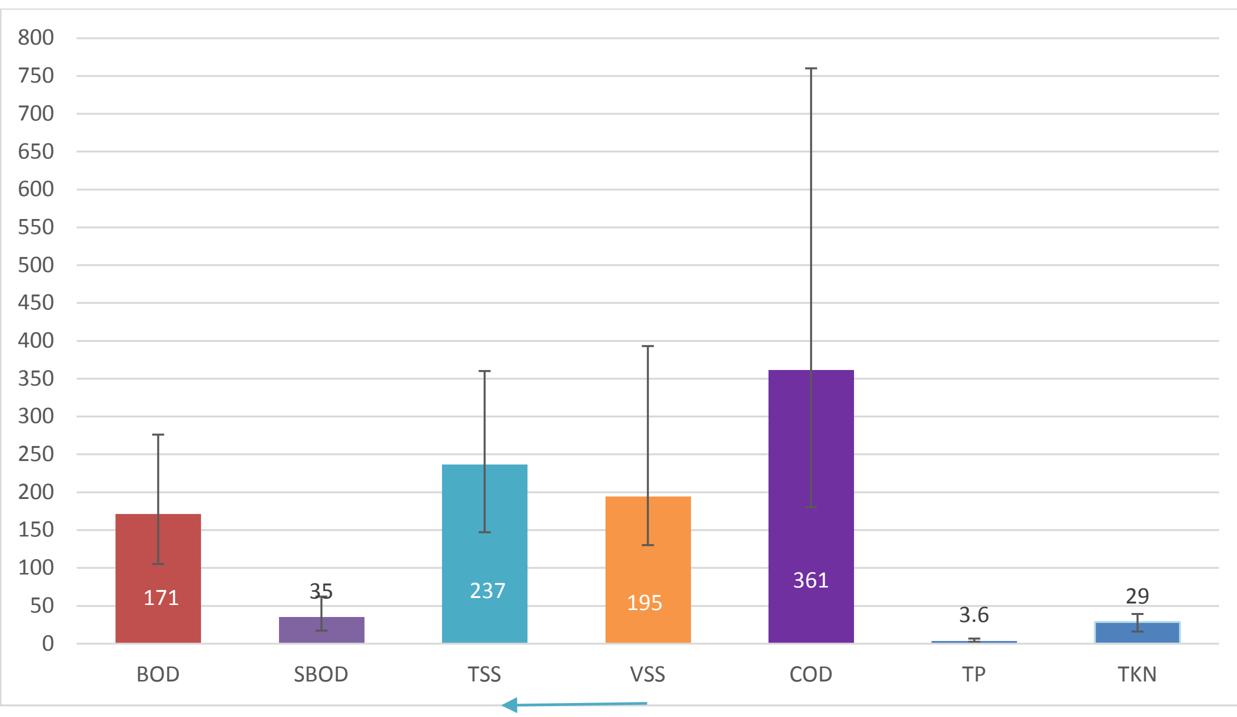


Figure 20. Influent Characteristics for Historical Period

Error bars represent range from maximum and minimum values in data set VSS concentration calculated using average VS% of average TSS.

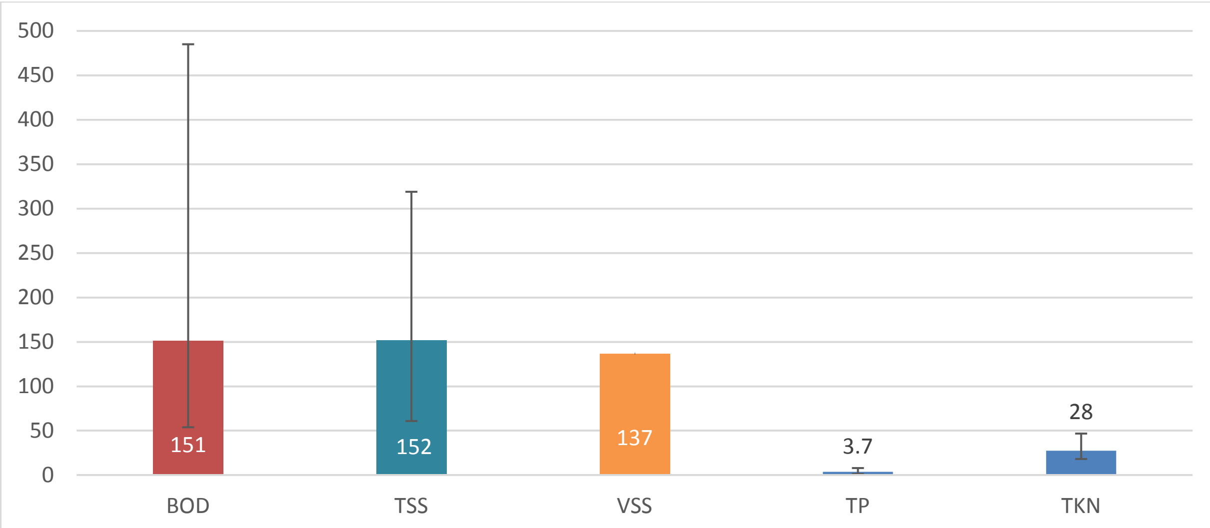


Table 2 shows the difference in influent characteristics during the time the OH influent was testing in the demonstration period (March – October 2015) and an earlier "Historical" time period (March 2012 – September 2014).

Table 2. Average Influent Characteristics of Demonstration Versus Historical Period

Period	BOD (mg/L)	SBOD (mg/L)	TSS (mg/L)	VSS (mg/L)	COD (mg/L)	TP (mg/L)	TKN (mg/L)
Demonstration	171	35	237	195	361	3.6	29
Historical	151		153	136		3.7	28

5.1.4 Organics Harvesting for Enhanced Primary Treatment

Section 3.1 provides a general overview of the OH system used in this pilot study with the description of the functionality and operations of the system. The full capacity of the OH pilot was not utilized as the volume of sludge would exceed the 780-gallon capacity of the 900-gallon sludge tank causing an unknown amount of captured material to exit the system unmeasured. One of ClearCove's goals of this demonstration was to evaluate the capture of the low density, highly organic material in the post-SCP sludge. These low density organic solids typically escape existing primary clarifiers due to continuous disturbed flow. There was a concern that these solids would exit the system in the decant of the thickening process and not reach the pilot digesters or BMP. Section 5.2 discusses the contents in the thickened sludge and decant in more detail.

Two separate chemical dosing rates were tested on the OH pilot, first an optimized dose of 80 milligrams per liter (mg/L) $FeCl_3$ +0.25 mg/L polymer and a lower dose of 50 mg/L $FeCl_3$ +1.0 mg/L polymer. The change from 80 mg/L $FeCl_3$ +0.25 mg/L polymer to 50 mg/L $FeCl_3$ +1.0 mg/L polymer took place because jar testing showed better COD removal with the latter. When the lab results came back two weeks later, they showed BOD removal rates of 50% minimum, 70% maximum, and 60% average. The chemical dosing rate was returned to 80 mg/L $FeCl_3$ + 0.25 mg/L polymer, and the average BOD removal rates increased to the expected removal rates of 58% minimum, 79% maximum, and 67% average.

Figure 21 illustrates the ability to control removal rates by adjusting chemical dosing rates. Another method to control removal rates is to adjust the distance between the organic sludge and the screened decanter, and the control of the captured constituents in tank concentrations by sludge removal rates. Previous mapping of the COD concentration at different liquid elevations in the tank showed that operating the screened decanter at higher liquid levels in the tank results in higher removal rates. This ability to control the concentration of organics in the primary effluent is important when considering the OH for biological nutrient removal (BNR) of secondary processes. It allows for a more measured and efficient delivery of necessary carbon to the BNR process. Additional research on the effect of OH on BNR processes would be beneficial.

The increase of $FeCl_3$ by 60% (from 50-80 mg/L) resulted in incremental improvements of less than 12% for BOD, with no impact on TKN and SBOD. Even at the higher dosing rate of 80 mg/L, the OH does not increase the total chemical consumption of the IAWWTF. A further evaluation of the chemical impact is provided in Section 7.

The impact of the chemical dosing change is shown in Figure 21 and Table 3.

Figure 21. OH Dosing Removal Rate Comparison During Optimization Testing

Error bars represent 95% confidence interval.

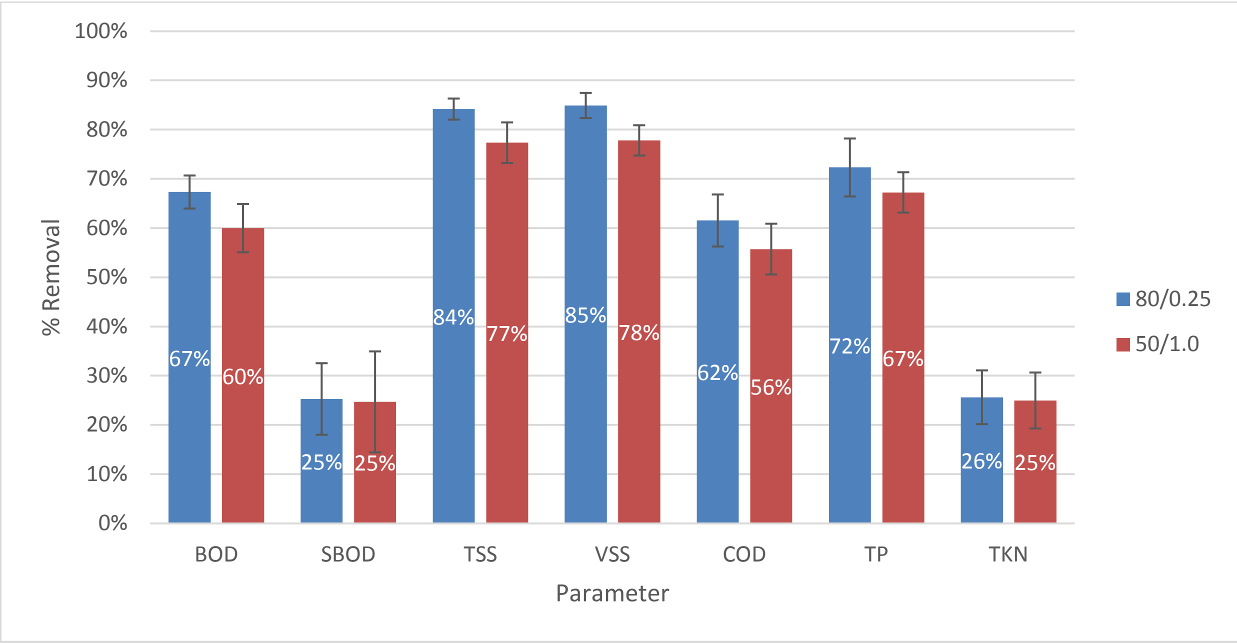


Table 3. Dosing Removal Rate Comparison During Optimization Testing

Note the 80/0.25 $FeCl_3$ polymer dosing rate was the optimized process for full pilot implementation and mass balance equation calculation.

Dose	BOD	SBOD	TSS	VSS	COD	TP	TKN
80/0.25	67%	25%	84%	85%	62%	72%	26%
50/1.0	60%	25%	77%	78%	56%	67%	25%

5.1.5 OH Comparison

Figures 22 to 28 show a comparison of the average removal rates of conventional primary clarifiers according to literature sources (see Section 10 for references) and the 24,000 GPD OH pilot unit as it applies to removal rates of $SBOD_5$, BOD_5, COD, TSS, VSS, TKN, and TP. Since the OH comparison is at pilot scale versus the full scale BJC tanks, the performance of the OH may improve in full scale tank depths. A comparison to conventional primary clarifier performance expectations is provided as the IAWWTF was experiencing an upset with temperature changes and a high rate of solids recycle impacting its primary clarifier performance during the demonstration period.

Due to a number of recycle streams that were discharged to the head of the primary clarifier and downstream of the influent composite sampler, the majority of the IAWWTF removal rates were negative and are thus not included in the following comparison charts.

Figure 22 shows the removal rates of the OH pilot at optimized for energy chemical dosing rates versus conventional primary clarification.

Figure 22. BOD Removal Comparison

"Conventional" from Wilson, Thomas et al. 2005,"Clarifier Design: Manual of Practice." Water Environment Federation. Error bars represent range between maximum and minimum removal rates.

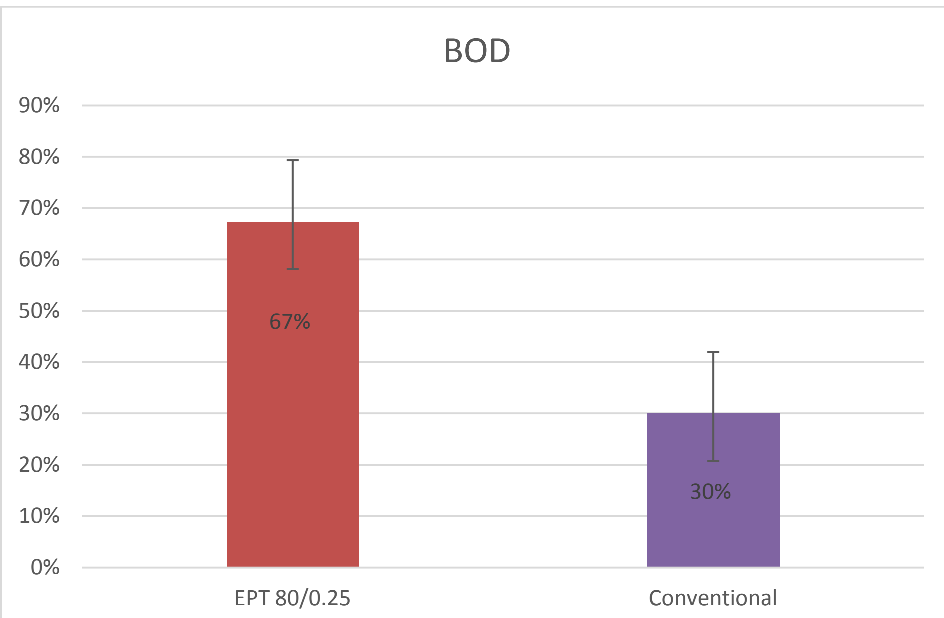


Figure 23 illustrates the increased TSS removal capabilities of the OH pilot at optimized for energy chemical dosing rates in comparison to conventional primary clarifiers from literature.

Figure 23. TSS Removal Comparison

“Conventional” an average from Wilson, Thomas et al. 2005 “Clarifier Design: Manual of Practice,” Water Environment Federation; and Puig, S. 2010 "The Effect of Primary Sedimentation on Full-scale WWTP Nutrient Removal Performance." Water Research, 2010

Error bars represent range between maximum and minimum removal rates.

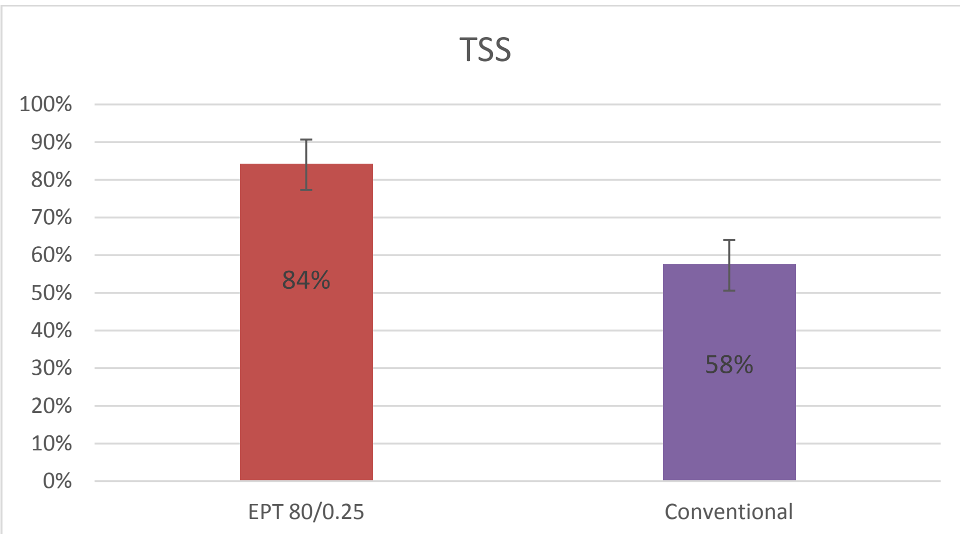


Figure 24 illustrates the OH pilot capture of VSS at optimized for energy chemical dosing rates in the primary stage which allows for increased sludge to be delivered to the digester in the primary sludge form.

Figure 24. OH VSS Removal

Error bars represent range between maximum and minimum removal rates

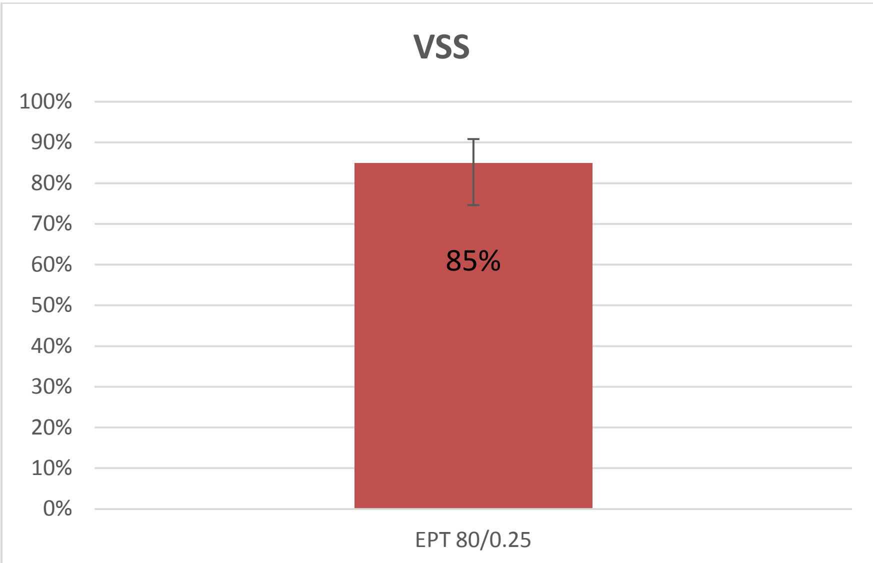


Figure 25 illustrates the high degree of phosphorous removal achieved by the OH pilot at optimized for energy chemical dosing rates which may reduce the need for operation of the Actiflo in the tertiary stage.

Figure 25. OH Phosphorus Removal

Error bars represent range between maximum and minimum removal rates

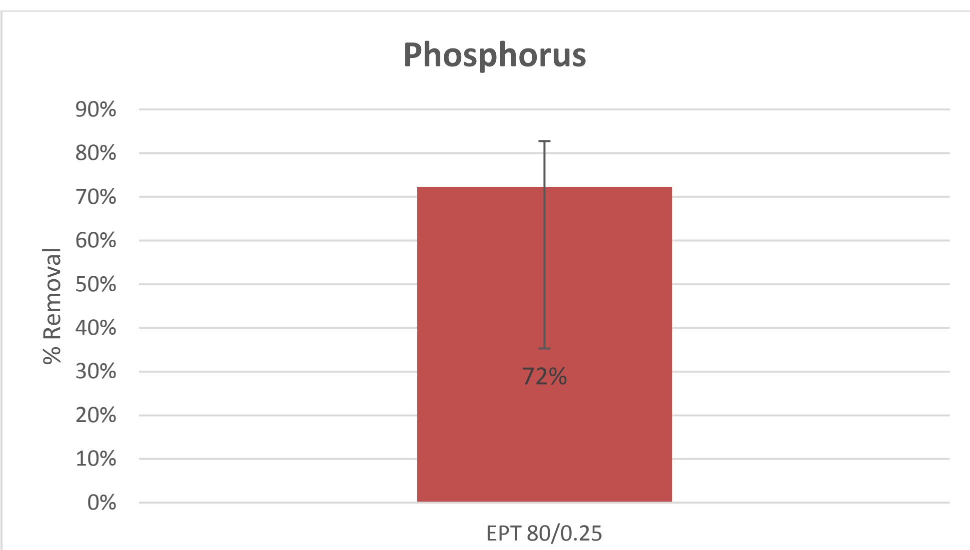


Figure 26 illustrates the higher COD removal rate of the OH pilot at optimized for energy chemical dosing rates in comparison to the conventional primary clarifier and supports the hypothesis that the OH pilot removes organics at a higher rate.

Figure 26. COD Removal Comparison

“Conventional” from Wilson 2005, Thomas et al. “Clarifier Design: Manual of Practice.” Water Environment Federation

Error bars represent range between maximum and minimum removal rates.

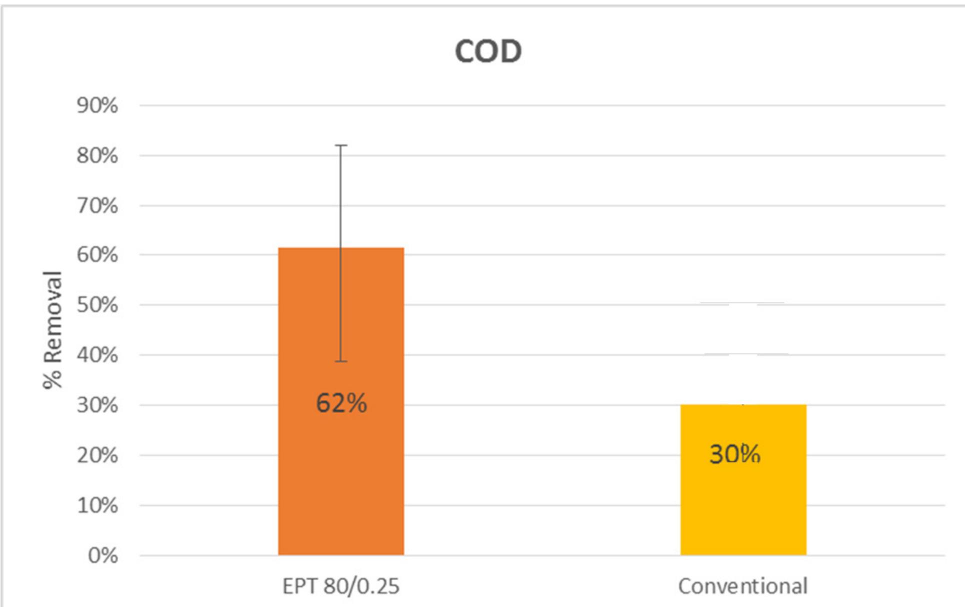


Figure 27 shows the OH pilot does not significantly reduce the TKN concentration.

Figure 27. TKN Removal Comparison

Error bars represent range between maximum and minimum removal rates.

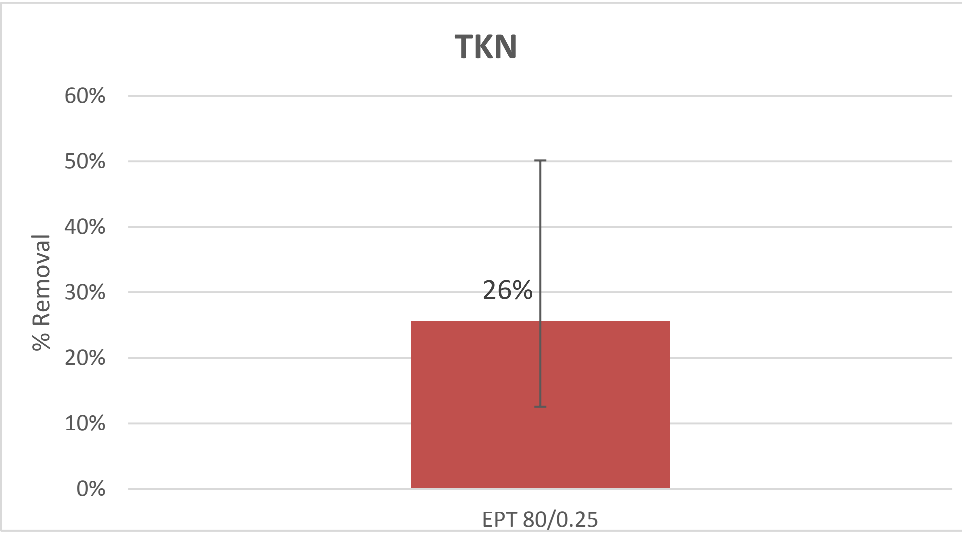


Figure 28 shows the SBOD removal rates of the OH pilot OH at optimized for energy chemical dosing rates. The OH does not have a significant effect on SBOD concentration and the removal rate was the same for both dosing combinations tested.

Figure 28. SBOD Removal Comparison

Error bars represent range between maximum and minimum removal rates

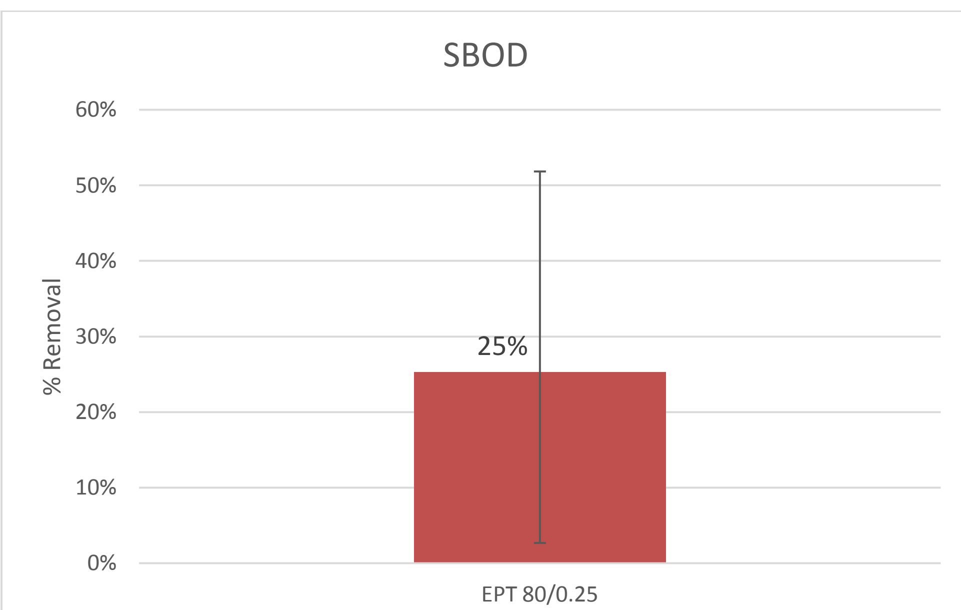


Table 4 summarizes the removal rate comparison between the OH pilot with the conventional primary clarifiers from the literature. On average, the OH pilot achieved approximately double the removal rate of conventional clarifiers, based on values found in the literature.

Table 4. Average Removal Rate Comparison Summary

	BOD	SBOD	TSS	VSS	COD	TP	TKN
OH 80/0.25	67%	25%	84%	85%	62%	72%	26%
Conventional Primary	30%[a]		58%[a,b]		30%[a]		

[a] Wilson, Thomas et al. 2005 “Clarifier Design: Manual of Practice.” *Water Environment Federation*, 2005.

[b] Puig, S. 2010, "The Effect of Primary Sedimentation on Full-scale WWTP Nutrient Removal Performance." *Water Research*, 2010, 3375-384.

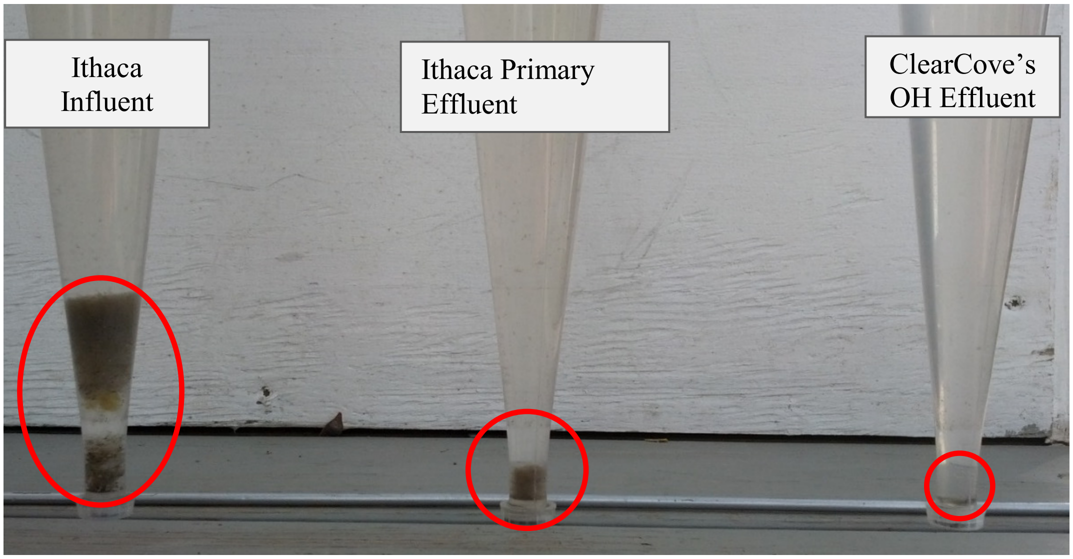
As previously stated, the IAWWTF was experiencing plant construction and upsets in its thickener process during the test period which impacted the removal rates and performance of the primary clarifier.

For additional details on OH pilot removal and sources for Conventional Primary Clarifier Removal rates, see Appendix B.

In addition to composite sampling and test results to indicate the performance of the OH pilot, Imhoff cones were taken of the raw IAWWTF wastewater, the OH effluent and IAWWTF’s primary clarifier effluent, as shown in Figure 5-29. The photo is typical of those visual tests.

Testing the OH pilot over the past two years has shown no visible fibers and <0.1 mg/L of settleable solids in the OH pilot effluent. Figure 29 also illustrates the small amount of solids often used as a correlation to the organic content of wastewater. In the case of IAWWTF, the small amount of solids/organics in the primary clarifier effluent requires a significant portion of the aeration energy to convert to CO_2 and biomass.

Figure 29. **Imhoff Cones**



Clarifier performance is commonly compared and evaluated using surface overflow rate as it describes capacity. It is difficult to compare conventional clarifiers and OH technology based on surface overflow rate or other criteria presented in Table 5.

In Figure 30, the flow pattern of effluent and organics of a conventional primary clarifier and OH are compared. The yellow arrows illustrate the lighter solids flow pattern while the blue represents the hydraulic flow pattern. One possible reason why the OH achieves better BOD removal as well as enhanced biogas production is the capture of the lighter colloidal organics that the conventional clarifier may not capture. Figure 30 shows that in a conventional clarifier the forward flow of water in the tank towards the effluent weir could carry these lighter organics out of the tank as there is no undisturbed settling. In the OH process, undisturbed settling occurs that allows for the colloidal organics to settle to the bottom of the tank, be captured, and sent to the anaerobic digester.

Figure 30. Conventional Primary Clarifier versus OH Flow Pattern

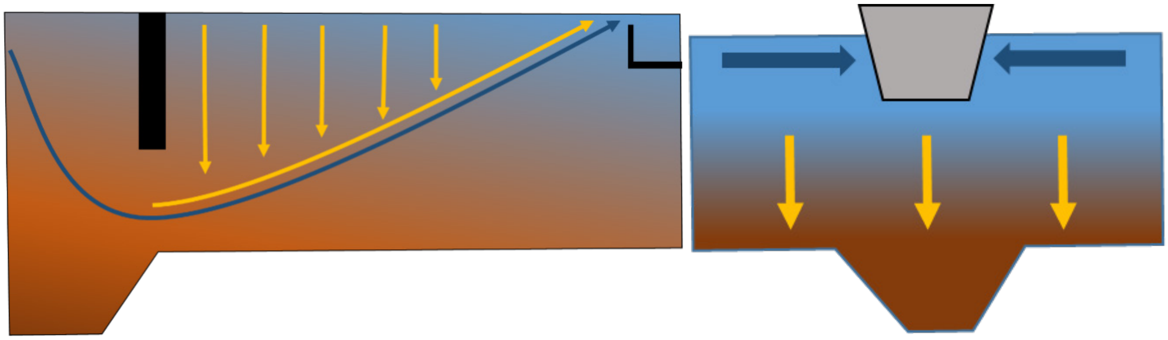


Table 5. IAWWTF Conventional Clarifier and ClearCove OH Comparison

Parameter	IAWWTF's Conventional Rectangular Primary Clarifiers	OH Pilot Unit
Flow	**Continuous**	**Intermittent** / Concurrent fill and decant cycles with flow equalization
Liquid Depth	13.4-ft minimum depth	Pilot unit depth varies from 2.8-ft. to 5-ft. – Full scale depths are 12-ft high water level to 5-ft low water level
Sludge removal	**Continuous** mechanical flights and chains + cross collectors. Sludge pumps run continuously.	**Intermittent** – no mechanical sludge movement devices so no disturbance during settling. Settled sludge is pumped out based on concentration of captured constituents.
Settling	The wastewater is always moving from inlet to the effluent weirs at a horizontal velocity of 0.009 FPS with the solids expecting to settle before reaching fixed effluent weir.	The wastewater is stopped in one tank and allowed to settle with no internal disturbances, Decanting of the supernatant starts at the end of the settle cycle with the screen box moving downward at the same rate as the liquid lowers, keeping a majority of the flow currents horizontal. The solids continue to settle during the decent of the screen box. One or more tanks are filling and settling as an equal amount of tanks are decanting.
Weir	**Fixed** at surface with velocities and flow density increasing the closer the liquid gets to the weir. There is no screen between the clarified water and the effluent weir.	**Moving** – descends at the same rate as the liquid level lowers thus pulling horizontally. The screen box / liquid interface is maintained at 0.009 FPS with the liquid velocity decreasing with the distance away from the screen box. The effluent must pass through a 50-micron screen. The screen section is submerged so liquid approaches the screen from the top, sides, and below thus increasing the surface area of the flow pathways and reducing velocity.
Filling	**Slow**, **varying** influent flow rates caused by VFD or gravity or multiple pumps. This negatively affects grit removal and solids settling because of a loss of velocity control. Continuous filling from one end results in a discharge flow rate equal to the influent flow rate thus providing variable flow rates to secondary processes.	**Fast**, **fixed** influent flow rate to optimize design to improve removal efficiencies of grit and medium density solids settling, high velocity creates good chemical / wastewater mixing, fast filling flow rate moves light tank solids to sludge hoppers, and allows time for settling. This can be done because the effluent discharge rate is isolated from influent flow rate. The flow enters at opposite ends and flows toward center of tank, colliding, creating turbulence over the sludge hopper, resulting in more mixing, the equalization of velocities, and solids settling over the hopper.

Table 5 continued

Parameter	IAWWTF's Conventional Rectangular Primary Clarifiers	OH Pilot Unit
Chemical Addition	Ferrous sulfate for odor + residual from Actiflo and belt press are returned to the head of the primary clarifier.	$FeCl_3$ + Polymer to move organic and nutrient removal are added to the influent to the OH. The projected impact on chemical use is lower for the OH than that of the existing primary clarifier and Actiflo.
Operational Flexibility	Adjust chemical use and sludge withdrawal volume and rate.	Can adjust; settle time, chemicals used and dose, liquid operating depths, screen loading rates, effluent flow, grit / medium density / hopper sludge withdrawal frequency and quantities are adjustable based on diurnal organic patterns, switch operating mode to optimize performance based on various design conditions.
Capture of fibers and solids >50 micrometers	Settling only that can be improved with chemical addition which will remove some large/fiber materials.	50-micron screened decanter, chemical addition, air scour, and stoppage of flow allows the capture of these constituents in the OH tank for SCP processing and delivery to the digester.

5.1.6 Testing of the OH Sludge (Pre-SCP) and Post-SCP Impact on Energy Generation

Figure 31 illustrated the process flow and sampling locations of the OH and SCP. The OH sludge captured in the 900-gallon tank is referred to as pre-SCP sludge. A grab sample was taken of this completely mixed pre-SCP sludge and tested for COD, TS, and VS%. This sludge was tested prior to being delivered to the pilot digesters and BMP unit.

The pre-SCP sludge was pumped through flow meter FM-5 to the SCP at 15-GPM. The pressate flows by gravity into a sump where it was pumped to the 300-gallon coned bottom tank. The post-SCP sludge volume was less than 280-gallons to prevent the supernatant from exiting the tank via the overflow.

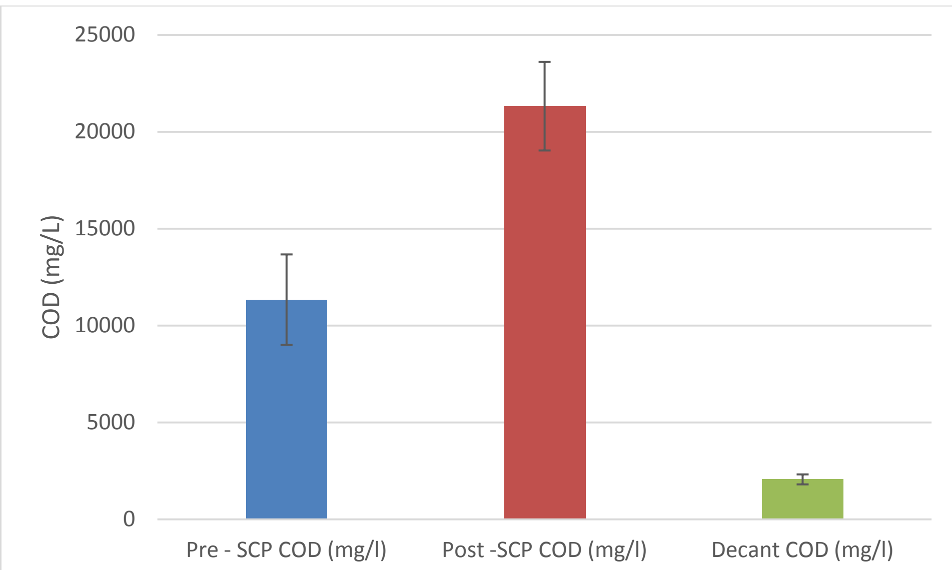
The post-SCP sludge was allowed to settle for approximately 45 minutes. A grab sample of the supernatant was taken from the top of the 300-gallon tank and tested for COD, TS, and VS%. Grab samples were taken from each of the 5-gallon pails of thickened sludge, combined, and then tested for COD, TS, and VS%. Then a Sludge Judge was used to try and quantify the volume of sludge and decant. This proved to be very subjective, as there was a small amount of clear supernatant and thickened sludge at the top and bottom respectively, with the majority being undefined.

5.2 SCP Operation and Performance Presented

The OH captures all solids greater than 50 micrometers by screening the supernatant and neutrally buoyant content by stopping the flow of the liquid and decanting the supernatant via the screen box. These organics would normally enter into secondary treatment requiring additional aeration energy to convert to biomass and CO_2. The OH sludge must be processed to remove the trash in the hopper and IFS sludge as there is no screening or grit removal prior to the OH. The SCP unit replaces both bar and fine screens, separates the organic and inorganic material captured in the OH, and dewaters the inorganic material it removes from the sludge. To show that the neutrally buoyant colloidal material was captured in the OH sludge, the sludge was tested for COD before (pre-SCP) and after (post-SCP) it was processed through the SCP unit. The results of this analysis are shown in Figure 31.

Figure 31. Average COD Concentrations of Pre-SCP Sludge, Post-SCP Sludge, and Decant Fractions

Error bars represent 95% confidence interval range.



It is common to thicken or dewater primary and secondary sludge. As these fine, neutrally buoyant solids are difficult to capture in conventional primary clarifiers, testing was performed to determine if such solids could be retained with the sludge or if they could be returned to the liquid train via decant or pressate.

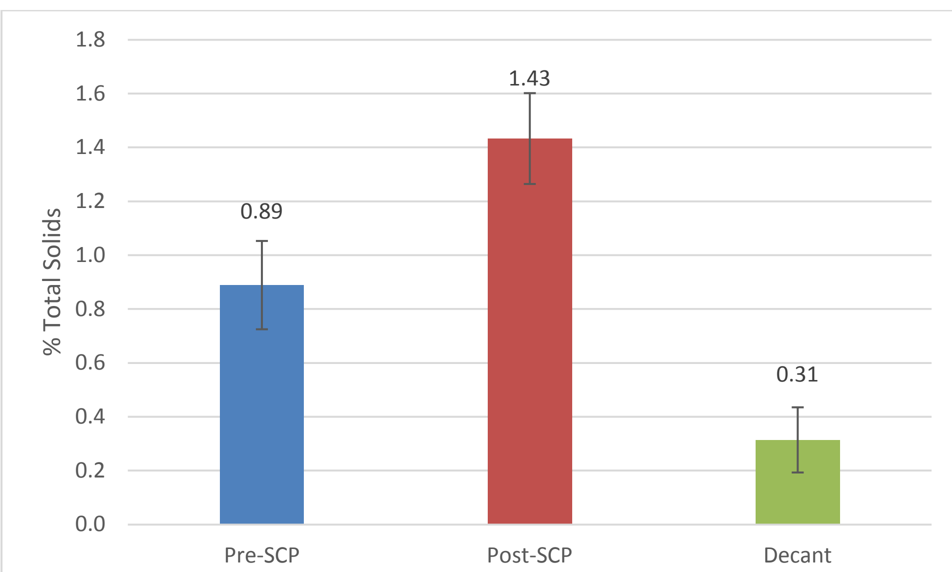
As previously described in Section 5.1, a grab sample was taken from the complete mixed pre-SCP (900-gal) tank. This sludge was then pumped through the SCP. The post-SCP sludge was pumped into a 300-gallon settling tank. No additional chemicals were added to the pre- or post-SCP sludges. The only chemicals added to this sludge were from the dosing of the raw OH influent with $FeCl_3$ and polymer. After 45 minutes of settling, grab samples of post-SCP supernatant and post-SCP sludge were taken. These three sample points were tested for COD, TS, and VS%. Three separate field tests were run on each sample. Refer to Section 6 on data quality, which describes how field tests were compared to certified lab results. Figure 31 shows consistent 10% COD concentration in the post-SCP decant.

In a full-scale installation with the addition of chemicals to the thickening process, a longer settling time and deeper sludge holding tanks would be expected to increase the TS% capture rate and likely the COD of the post-SCP sludge, with a reduction in the decant COD concentration.

The demonstration showed a consistent TS% by weight of 0.31% in the post-SCP decant; 1.43% TS in post-SCP sludge; and 0.89% TS in the pre-SCP (Figure 32). As with the COD information above, a higher % TS would be expected in a full-scale application, as it is commonly recognized that conventional primary sludge can be thickened to 4-5%.

Figure 32. % Total Solids of Pre-SCP Sludge, Post-SCP Sludge and Decant Fractions

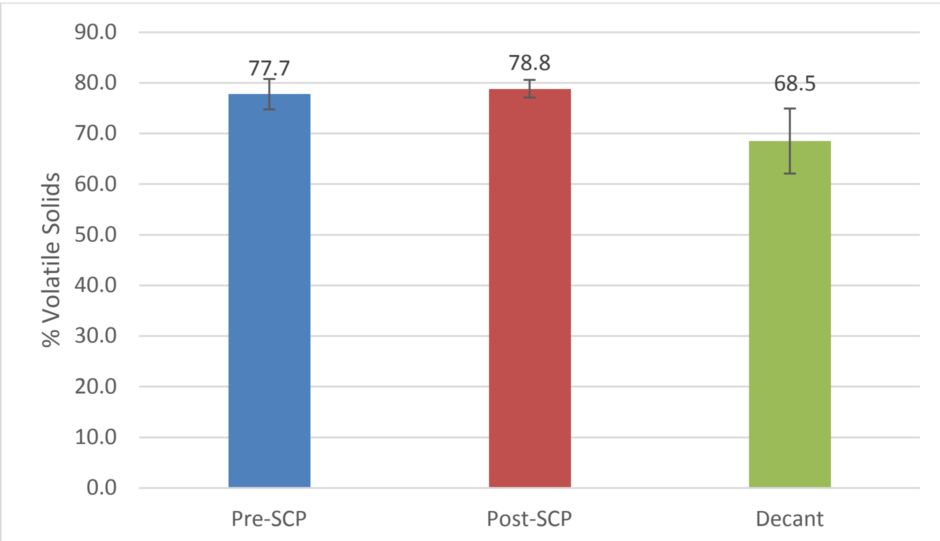
Error bars represent 95% confidence interval range.



The comparison of the %VS content in the pre-SCP, post-SCP sludge, and post-SCP decant followed the same sampling and test procedures with equally high quality of data achieved. The pre-SCP and post-SCP %VS were consistent with variations in the %VS of the decant due to the low solids content, as shown in Figure 33.

Figure 33. %Volatile Solids of Pre-SCP Sludge, Post-SCP Sludge and Decant Fractions

Error bars represent 95% confidence interval range.



Shearing organic matter to release internal organic content increases the organic content of the liquid. The same would apply for compressing organic matter, such as garbage disposal and waste foods (beans, corn, etc.), to extract the more rapidly biodegradable organic internals that are protected by the seed casing. Traditional primary treatment processes use grinding and screening in the headworks that can result in a small increase in BOD going to the secondary treatment. When working toward an energy neutral or positive treatment facility, all opportunities to reduce energy consumption and increase energy production should be considered. Anaerobic digester research commonly states that the smaller the organic particle size and greater its surface area, the more rapid the biodegradation to biogas and greater the solids destruction -- all resulting in enhanced biogas production. The removal of trash and grit by the SCP also improves the overall mechanical operations of the anaerobic digester, thus providing a more stable environment for anaerobic digestion.

A grab sample of the post-SCP sludge prior to settling should have been taken and analyzed to measure the increase in COD or VS from the SCP processing. As the focus of this demonstration was on the biogas generation of the post-SCP thickened sludge, the sampling of the complete mixed post-SCP was not performed. While a potential opportunity for future research exists, numerous studies confirm that grinding and screening of organics increase the organic content.

For more details of the SCP operation data, see Appendix C.

5.3 BMP Operation and Performance

Seven BMP tests were conducted in parallel with the pilot digesters over the course of the project. The same sludge types fed to the pilot digesters were used in the BMP experiments.

The day leading up to a test, samples of each substrate and inoculum were collected for TS and VS analyses. The substrates, OH, IAWWTF primary, and IAWWTF thickened sludge, were used as the feedstock. The inoculums used to seed the BMP reactor with active biology were collected from the IAWWTF full-scale digester or from the pilot digester units.

The results of the volatile solids analysis were entered into the software platform provided by Bioprocess Controls, which calculated the volume (mL) of each substrate and inoculum to be placed in each bottle based on a chosen inoculum/substrate (I/S) ratio. The I/S ratio for the experiments run during this project was 1.5:1. This ratio means there was 1.5 times more inoculum VS loaded than substrate VS into each bottle. This ratio was recommended by Bioprocess Controls.

The double VS loading of OH pilot digester 4 was simulated by adjusting the I/S ratio so that twice the mass of VS was loaded into the bottle by comparison to the normally loaded OH bottles. The mass of VS per mass of sludge was determined by analysis of the sludge for each test.

The average of the test results is shown in Figure 34 and Table 6. On average, it appears that the ClearCove OH sludge generated approximately 1.3 times more methane than the IAWWTF Primary Sludge. The tests had an average length, or detention time, of approximately 11 days. The BMP equipment required no maintenance over the course of a test aside from adding water to the incubator bath.

The seven BMP tests performed during this reporting period were as follows:

- 6/24 – 7/1.
- 7/1 – 7/8.
- 7/8 – 7/24.
- 7/25 – 8/11.
- 8/15 – 9/2 (not included in averages due to abnormal result).
- 9/3 – 9/15.
- 9/17 – 10/13.

The wider variability in the OH 2X measurements is indicated by the wide range of the 95% confidence interval bar in Figure 34.

Figure 34. Average BMP Results

Error bars represent 95% confidence interval range.

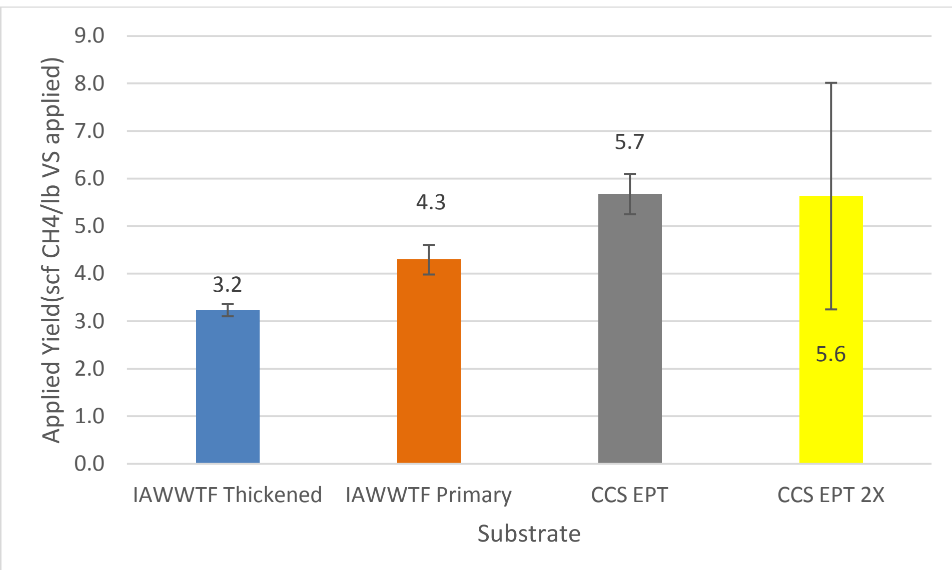


Table 6. Average BMP Results

Substrate	VS Load (g)	Total Methane (nmL)	Average Applied Yield (scf methane/lb VS applied)
IAWWTF Thickened	1.56	315	3.2
IAWWTF Primary	1.59	426	4.3
OH	1.48	523	5.7
OH 2X	3.08	1,093	5.6
IAWWTF WAS	0.87	95	1.8

Only methane generation was measured as part of the BMP experiment as the BMP testing equipment included a CO_2 scrubbing unit.

The double volatile solids loading of the OH 2X reactors produced a similar average applied yield to the regularly loaded OH reactors. This result indicates that the OH sludge can potentially be loaded at double the rate without decreasing the biogas yield, thus allowing for twice the amount of methane to be produced in total.

The waste activated sludge (WAS) from the IAWWTF activated sludge process was also tested for BMP. The results of the test showed that the WAS had a much lower methane yield than the other sludge types at 1.8 scf methane/lb VS applied as shown in Table 6.

Additional research and BMP testing would be beneficial on mixtures of OH and WAS sludge to evaluate the impact of co-thickening OH sludge and WAS.

For details on the BMP experiment data, see Appendix D.

5.4 Pilot Digester Operation and Performance

The first pilot digester was used as a control to validate the scalability of the pilot digester experiment by comparison with the full-scale IAWWTF digester. Digester 1 (PD-1) was fed the same thickened sludge as the IAWWTF full-scale digester at the same rate of 50 lb VS/kcf/day.

The second digester (PD-2A) was fed primary sludge from the IAWWTF primary clarifiers. This digester was also fed at the target rate of 50 lb. VS/kcf/day. PD-2A biogas generation was used as the reference for comparison of biogas generation from the OH sludge.

The third digester (PD-3) was fed OH sludge from the OH unit at 50 lb VS/kcf/day for the purpose of measuring the increase in biogas production from OH sludge relative to conventional primary sludge delivered at the same loading rate.

The fourth digester (PD-2B) was fed OH sludge at double the target loading rate, 100 lb VS/kcf/day. The purpose of the double feed rate was to measure the increase in biogas production from OH sludge relative to conventional primary clarifier sludge when the more rapidly digestible OH sludge is fed at a higher rate.

The digesters were operated over the course of several months, starting in April and concluding in October 2014.

5.4.1 Pilot Digester Performance

Table 7, Table 8, Figure 35, and Figure 36 show the performance of the pilot digester units over the course of the project. The data show that the OH sludge (PD-3, PD-2B) generated just over two times the biogas in comparison to the IAWWTF primary sludge (PD-2A) per pound of VS fed to the digester; and OH sludge generated 1.7 times more biogas than the primary sludge per pound of VS destroyed.

It should be noted that the digester gas meters measured biogas generation however the yields are presented as methane using the methane percentage measurements collected over the course of the demonstration.

Table 7. Pilot Digester Data

Sludge	Dates	Number of Data Points	Detention Time (d)	Number of Digester Volumes	VS Loading (lb/kcf/d)	VS Destroyed (%)
IAWWTF Plant	2013-2014	548	22	24	69	53%
IAWWTF Thickened Sludge (PD-1)	7/14-9/14	63	13	4.7	62	41%
IAWWTF Primary Sludge (PD-2A)	4/11-6/17, 7/21-8/15	94	17	5.7	51	38%
OH (PD-3)	4/11-6/17, 8/18-10/22	134	19	7.2	46	51%
OH 2X (PD-2B)	9/3-10/22	50	9.4	5.3	83	39%

Table 8. Additional Pilot Digester Data

Sludge	Biogas Flow (sL/d)	Methane Content (%)	Methane Yield (scf CH4/ lb. VS fed)	Methane Yield (scf CH4/ lb. VS removed)	BMP Yield (scf CH4/ lb. VS fed)
IAWWTF Plant	2,380,000	68	4.6	14.8	3.3
IAWWTF Thickened Sludge (PD-1)	169	71	5.0	12.2	3.3
IAWWTF Primary Sludge (PD-2A)	355	64	4.1	13.4	4.4
OH (PD-3)	432	71	7.3	29.3	5.9
OH 2X (PD-2B)	394	65	8.1	20.9	7.6

Figure 35. Pilot Digester Applied Yield

Error bars represent 95% confidence interval range.

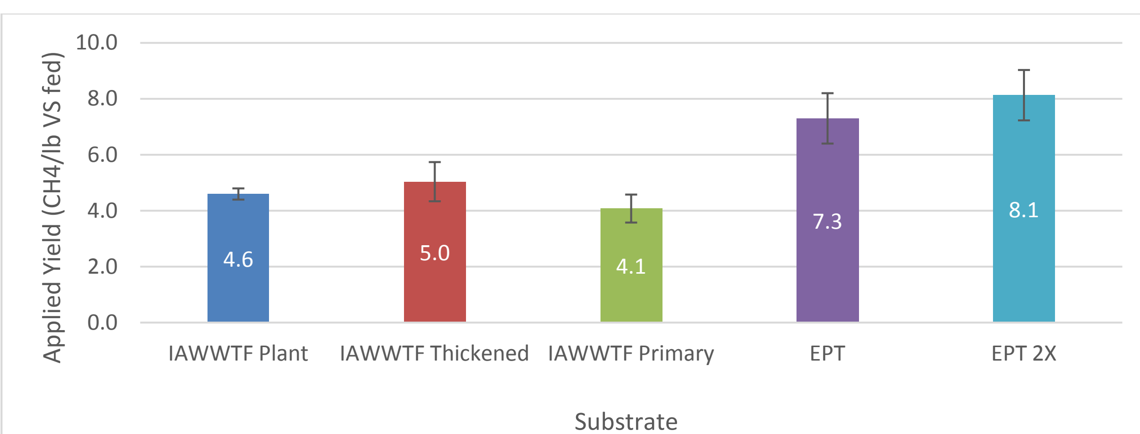
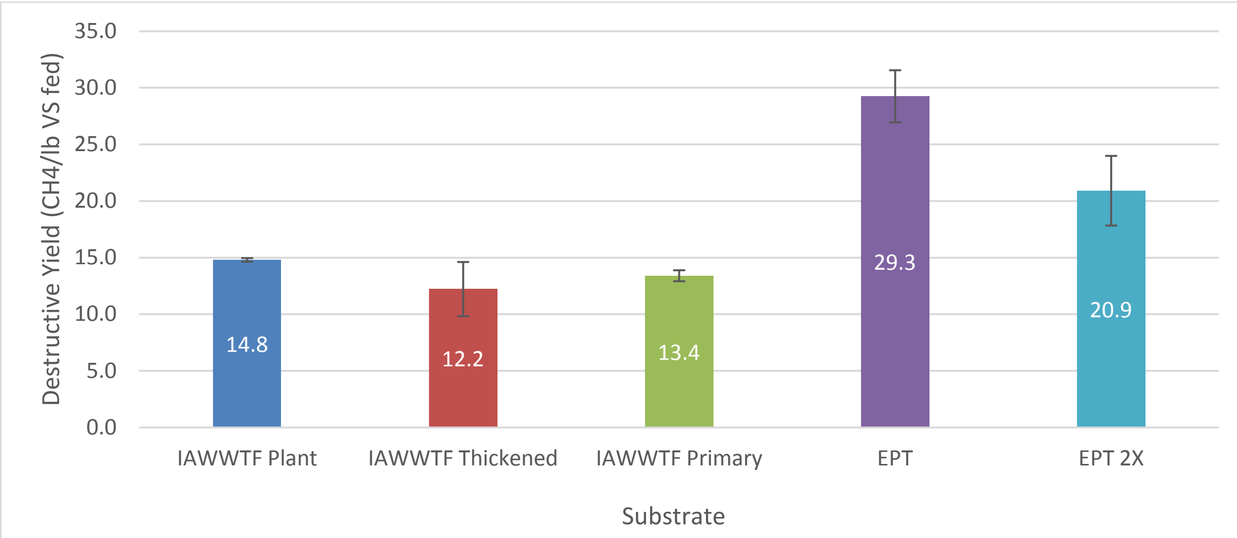


Figure 36. Pilot Digester Destructive Yield

Error bars represent 95% confidence interval range.



The destructive yields were calculated using days when there were measurements of the following three parameters: (1) feeds solids, (2) digested solids, and (3) biogas amount. The solids sampling schedule was three times per week and biogas sampling was daily. When the digested solids value exceeded the feed solids value (a negative destruction) due to a sampling error or digester upset, the yield was not calculated for that day.

For the enhanced primary sludge, this resulted in 22 data points from PD-3 and 11 data points from pilot digester PD-2B. The data collection period for PD-3 was 8/18/14 to 10/22/14 and for PD-2B it was 9/3/14 to 10/22/14.

The daily destructive yields for these combined 33 data points:

- Averaged 28.3 scf methane/lb VS destroyed.
- Had a range of 0.5 to 130.5 scf/lb VS and a median value of 19.2 scf/lb VS.
- The 95% confidence interval of the mean was 18.6 to 38.0 scf/lb VS.
- The low value of 0.5 scf/lb VS was due to a small biogas flow due to small biogas flows on those days (small numerator).
- The high value of 130.5 scf/lb VS was due to a small amount of VS destroyed (small denominator).
- Thus, Had a standard deviation of 28.4 scf/lb.

The average destructive yield of the OH sludge is high, however the 95% confidence interval of the mean has a wide range that incorporates “typical” municipal primary sludge results, all be it at the lower end of the CI range. A 2011 study at the Gloversville-Johnstown Joint Wastewater Treatment facility showed a methane yield of 21.9 scf/lb VS destroyed for their anaerobic digester operation, indicating that it is possible for municipal sludge to achieve a yield in the ranges experienced during this pilot study.

In comparison, the destructive yield of the Ithaca Primary Sludge was calculated based on 9 data points from PD-2A during 7/22/14 to 8/15/14. This pilot digester had much less variability than the EPS pilot digesters, and the 95% confidence interval of the mean ranged from 11 to 16 scf methane/lb VS destroyed. The same feed source for each digester was used throughout the pilot testing. The calculations were not done on paired days however the results from multiple days were used for the calculations and statistics to determine representative results.

The results also show that PD-2B, the digester being fed OH sludge at twice the target rate, achieved VS destruction of 39%, which was similar to that of both PD-1 and PD-2A. This VS destruction rate was achieved despite the PD-2B having a shorter detention time of only 9 days. This supports the hypothesis that the OH sludge could be fed at a higher rate because it is more readily biodegradable. The two OH digesters (PD-3 and PD-2B) showed different methane yields due to the lower VS destruction and detention time in PD-2B and the longer more stable operation in PD-3.

The increased methane yield of the enhanced primary sludge is expected to be a result of a number of factors including:

- **Enhanced capture of colloidal particles in the OH unit –** This occurs because of the nature of the OH process involves completely stopping the flow of water and allowing an undisturbed settling period to occur, allowing for the lighter colloidal and supracolloidal organics, which are believed to be more readily biodegradable, to settle to the bottom of the tank where they can be extracted as sludge. A conventional primary clarifier may not capture these colloidal organics because the influent flow typically starts low near the sludge hopper and rises to the effluent weir carrying the lighter organics out over the weir. Additional studies in this area would help to confirm this hypothesis.
- **The higher BOD concentration of the OH sludge –** The OH pilot unit showed enhanced removal of BOD from the wastewater stream versus conventional primary clarification. This greater BOD removal from the liquid effluent results in greater BOD being captured within the tank and sent to the anaerobic digester for methane production.

- **The reduced particle size of the enhanced primary sludge versus Ithaca's conventional primary sludge as a result of colloidal organic capture and processing through the sludge cleaning and enhancement process –**. Studies have shown that reduced particle size increases available surface area to microorganisms and can support the digestion of organics.[34] As mentioned before, the OH has shown capture of colloidal organics, which have a smaller particle size than other particulate organics.
- **The SCP increases the available organic concentration of the enhanced primary sludge –** The sludge from the OH unit was tested for COD concentration before and after it was processed through the SCP. Results, as shown in Section 5.2, showed that the COD concentration increased by double after processing by the SCP, confirming the hypothesis that the SCP increases the concentrations of organics. This increase in organics is attributed to the shearing of encased organics, allowing for the trapped organics to be released into the sludge. In addition, the SCP's removal of inerts (trash) from the enhanced primary sludge could be expected to be a contributing factor to the higher destructive yield compared to typical primary sludge.
- **The IAWWTF also experienced problems with its thickener during the demonstration period resulting in a high solids concentration overflow to be recirculated to the head of the primary clarifiers –** The solids recirculated to the clarifiers would include both primary sludge and WAS. This WAS being recirculated and consequently co-settled in the primary clarifiers with the IAWWTF primary sludge could potentially have contributed to a lower methane yield of sludge collected from the primary clarifiers.

The VS reductions achieved by the pilot digesters as shown in Table 7 are low relative to the full-scale digester due to the shorter detention time of the pilot-scale digesters versus the full-scale digester.

For more detailed data on the pilot digesters operation, see Appendix E.

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3 Palmowski, L.M. and J.A. Muller, "Influence of the size reduction of organic waste on their anaerobic digestion," Water and Technology, IWA Publishing

4 Izumi, Kouichi, Yuki Okishio et al., "Effects of particle size on anaerobic digestion of food waste," International Biodeterioration & Biodegradation

6 Data Quality

6.1 Pilot Digesters

Three critical parameters were the specific focal points in this experiment to ensure the results of the digester pilot were dependable:

- Total Solids.
- Volatile Solids.
- Biogas Generation.

6.1.1 Total Solids and Volatile Solids

To maintain the target loading rate to the pilot digesters, % TS and % VS analyses were performed multiple times per week. Due to the two-week time frame to receive results from the third-party laboratory, the TS and VS analyses were performed in IAWWTF's on-site laboratory. To ensure the accuracy of the pilot digester loading, samples were also sent to the third-party laboratory to verify the results from on-site testing. Figure 37 and Figure 38 show the TS and VS concentrations measured at both the plant and the third-party laboratory for each feed tank (FT) and pilot digester (PD). The numbers in white indicate the average TS or VS concentration while the black bars indicate the 95% confidence interval range for the data set. It can be seen that the results from the on-site testing and lab were tightly grouped and similar.

Figure 37. Total Solids Concentration – Plant and Lab Comparison

Error bars represent 95% confidence interval range.

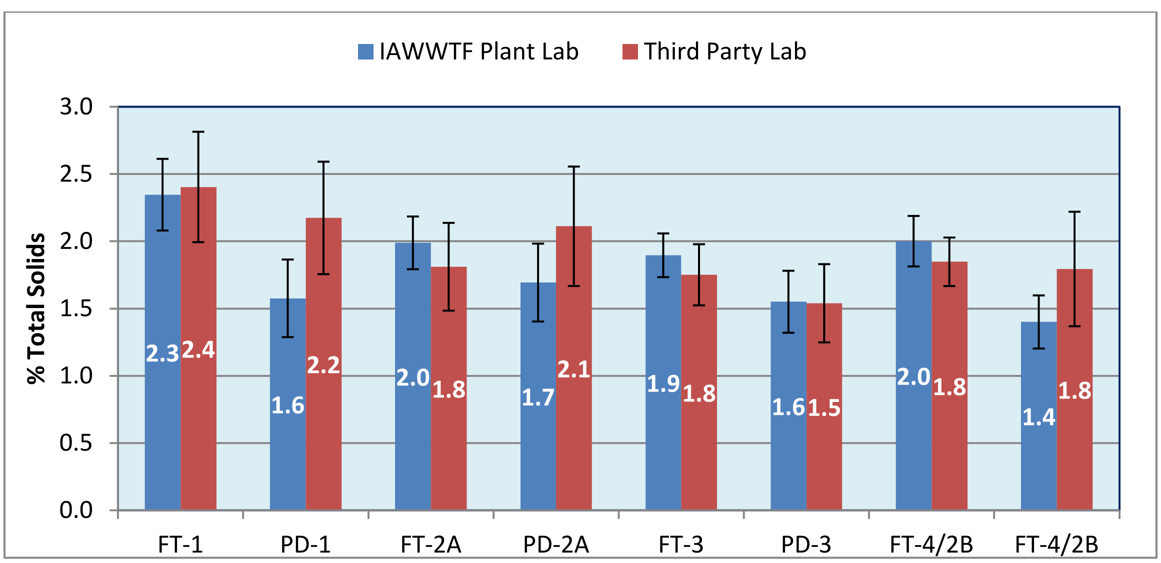
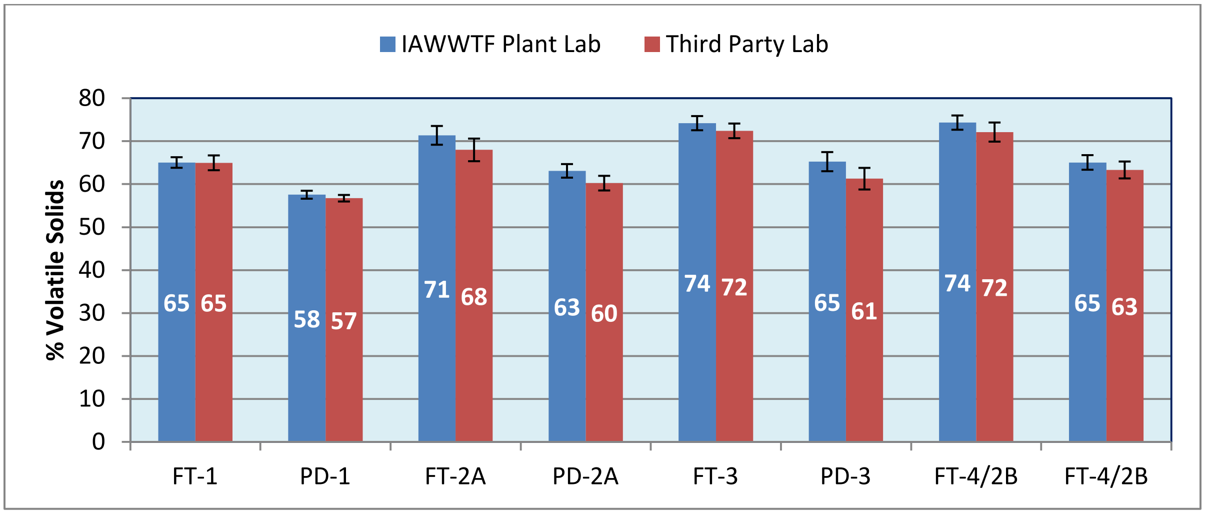


Figure 38. Volatile Solids Concentration – Plant and Lab Comparison

Error bars represent 95% confidence interval range. See Appendix G for more detail on TS and VS data.

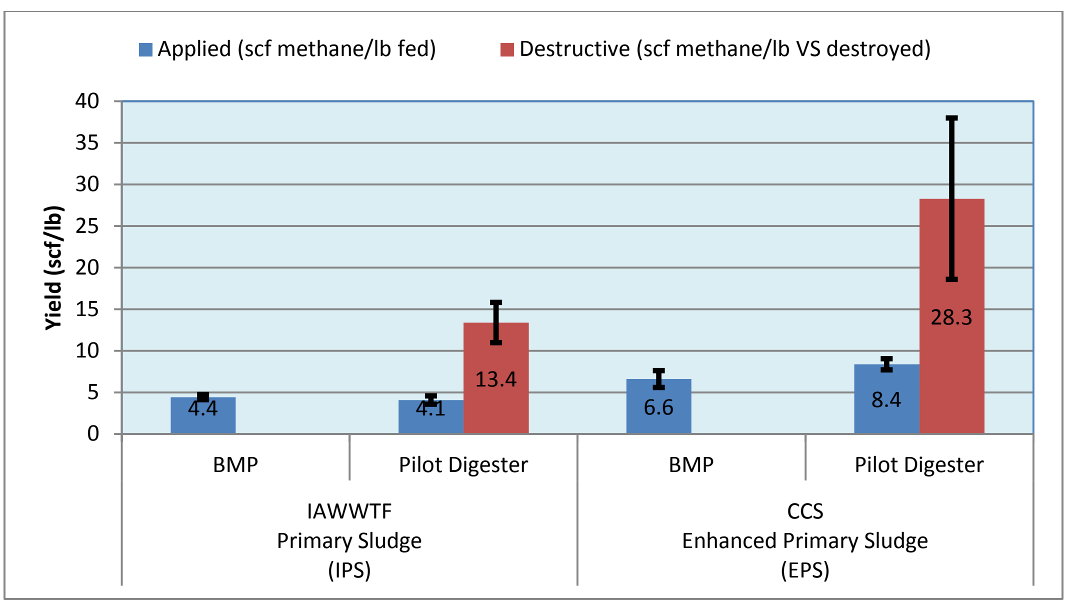


6.1.2 Biogas Generation

To validate the biogas generation benefits of the OH sludge, two methods were used to measure the amount of methane generated by the sludge, the continuous flow pilot digesters (PD) and batch biochemical methane potential (BMP) testing. The methane yield from the OH sludge is compared to the methane yield from the IAWWTF primary sludge as shown in Figure 39.

Figure 39. Pilot Digester and BMP Biogas Results Comparison

Error bars represent 95% confidence interval range.



The height of the columns in Figure 39 indicate the average value from all the demonstration results and the black, vertical bars indicate the range of the 95% confidence interval for the population mean. For the IAWWTF primary sludge, the BMP testing had an average applied yield of 4.4 scf methane/lb VS fed, and the pilot digester showed an applied yield of 4.1 scf CH_4/lb VS fed. The average applied yield for the OH sludge was 6.6 scf CH_4/lb VS fed from the BMP testing and 8.4 scf CH_4/lb VS fed from the pilot digesters. The applied yields between the BMP and pilot digester tests are shown to be statistically similar as their 95% confidence intervals are overlapping with one another, indicating that there is a high probability that the average from the sample population will be the same. The applied yield between the two sludges are statistically different from each other because the 95% confidence intervals do not overlap.

Figure 39 also indicates the destructive yield (scf CH_4/lb VS destroyed) from the pilot test results. The 28.3 scf CH_4/lb VS destroyed average result for the OH sludge is statistically different than the 13.4 scf CH_4/lb VS destroyed result for the IAWWTF primary sludge.

It is noteworthy that only one combined set of results is presented for the OH sludge. Two sets of data were collected for this sludge at different loading rates in both the BMP tests and pilot digesters. The methane yield results were similar to each other and have been combined into one set of results for reporting.

One observation that can be made from the methane yield results is that OH sludge produces more methane per pound of sludge, between 1.6 and 2.1 times more, than IAWWTF primary sludge.

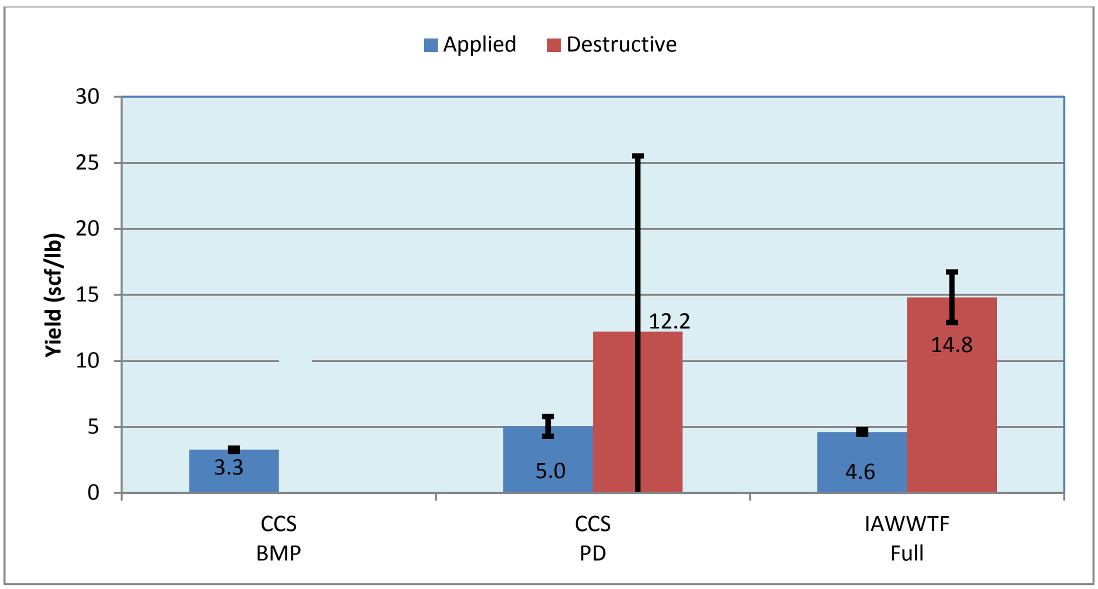
6.1.3 Scalability

To validate the biogas generation from the pilot anaerobic digesters, two methods were used as previously mentioned, the continuous flow pilot digesters (PD) and batch biochemical methane potential (BMP) testing. The methane yield of the IAWWTF thickened sludge from both methods was compared against the IAWWTF full-scale digester methane yield to validate the pilot test results.

As shown in Figure 40, both the applied yield (scf methane/lb. VS fed) and the destructive yield (scf methane/lb VS destroyed) of the control pilot digester were statistically similar to those of the full-scale IAWWTF primary anaerobic digester. The destructive yield from the BMP studies is not included because it can be difficult to accurately measure. The applied yield of the BMP, pilot digester, and full-scale digester were also statistically similar. This result indicated that the demonstration results should adequately reflect the actual performance at full scale.

Figure 40. Scalability of Demonstration Results

Error bars represent 95% confidence interval range



7 Discussion of Plant-Wide Impacts and Energy Balances

Using the data collected during the demonstration project, a plant-wide mass balance was prepared and the predicted impacts of installing a full-scale OH system on the following processes calculated:

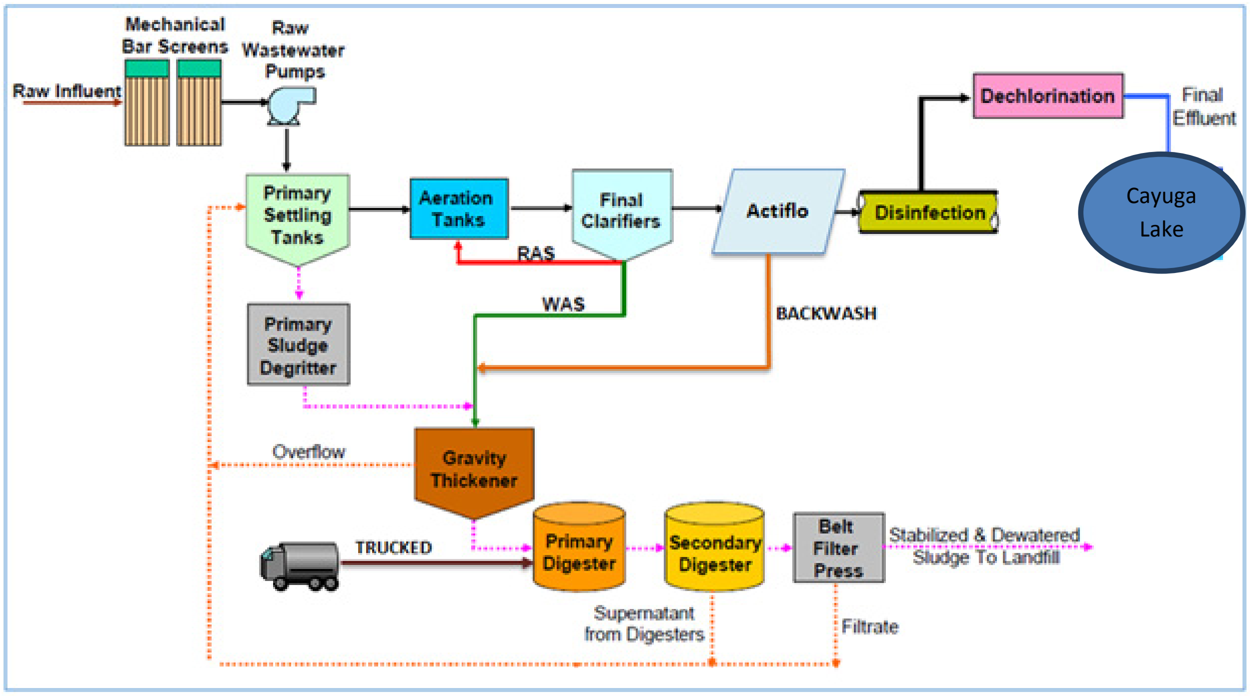
- Primary treatment.
- Aeration.
- Digestion.
- Grit and screening.
- Sludge processing.
- Return flows.
- Chemical consumption.
- Energy consumption.

7.1 Mass Balance

During the demonstration period of July 31 to September 12, 2014, the IAWWTF was undergoing a primary clarifier repair, an aeration upgrade, process tank cleanout, and the start-up of the solids waste facility. Some of these on-site activities may have influenced the primary clarifier effluent data, thus skewing the actual performance. For this reason, a mass balance using historical data from January 2013 to September 2014 was developed for use as the baseline. Another mass balance was prepared for the expected "future" impact of the OH and two SCPs, replacing the existing primary clarifiers for average day flows and the gravity sludge thickener.

As shown in the Process Schematic of the IAWWTF (Figure 41), the major unit processes consist of preliminary, primary, secondary, tertiary and solids handling.

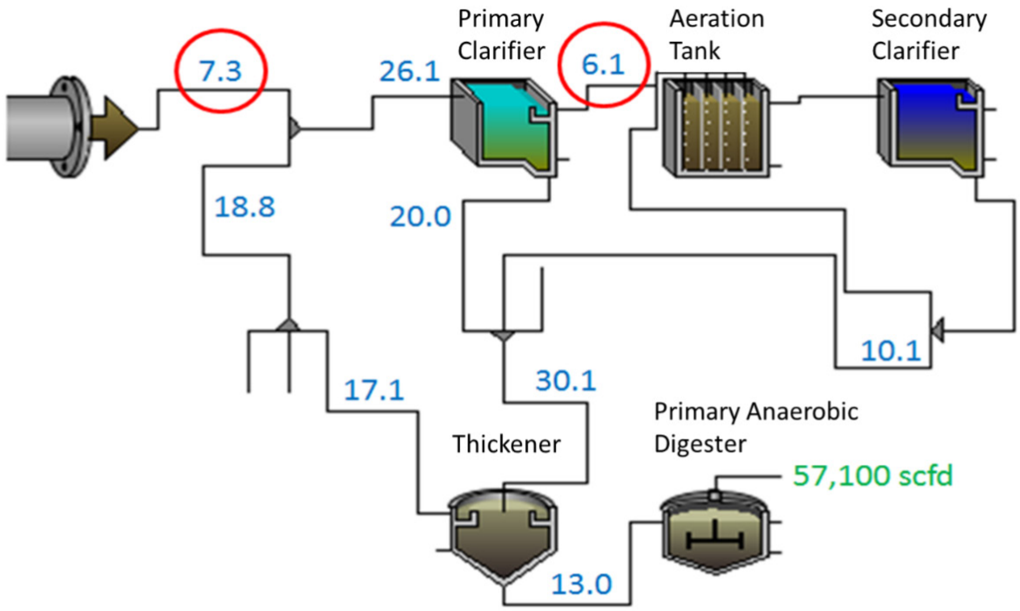
Figure 41. IAWWTF Schematic



Preliminary treatment consists of screening and pumping. Primary treatment consists of gravity clarification for suspended solids removal and primary sludge degritting. Secondary treatment consists of aeration and final clarification for removal of soluble organics with some degree of nitrification. Tertiary treatment includes high rate flocculated settling using the Actiflo® technology followed by disinfection with hypochlorite addition and dechlorination with sulfur dioxide gas addition prior to discharge into a deep region of Cayuga Lake. The solids handling systems include combined thickening of primary sludge, waste activated sludge (WAS), and the backwash from tertiary treatment. Thickened solids are then anaerobically digested and dewatered by a belt filter press (BFP). Sludge cake is currently disposed in a landfill. Thickener overflow, secondary digester decant, and BFP filtrate are returned to the influent to primary clarification.

Figure 42. Historical Mass Balance of Volatile Solids with Current Primary Treatment

Influent VSS averaged 7,300 lb/day and primary effluent VSS was 6,100 lb/day, which are indicated by the red circles shown in the figure. This represents a total 16% VSS removal rate by the primary clarifier.



As shown in Figure 42, for the historical data period, influent VSS averaged 7,300 lb/day and primary effluent VSS was 6,100 lb/day, which equates to a removal rate of only 16%. Part of the reason for such a low removal is the magnitude of the VS load from the return streams (18,800 lb/day). The thickener performed poorly during the demonstration due to diurnal thermal variations causing rising sludge in primary clarifiers and poor settling in the thickeners. The amount of methane generated in the biogas from anaerobic digestion of the plant residuals has been determined to be an average of 57,100 scfd (standard cubic feet per day).

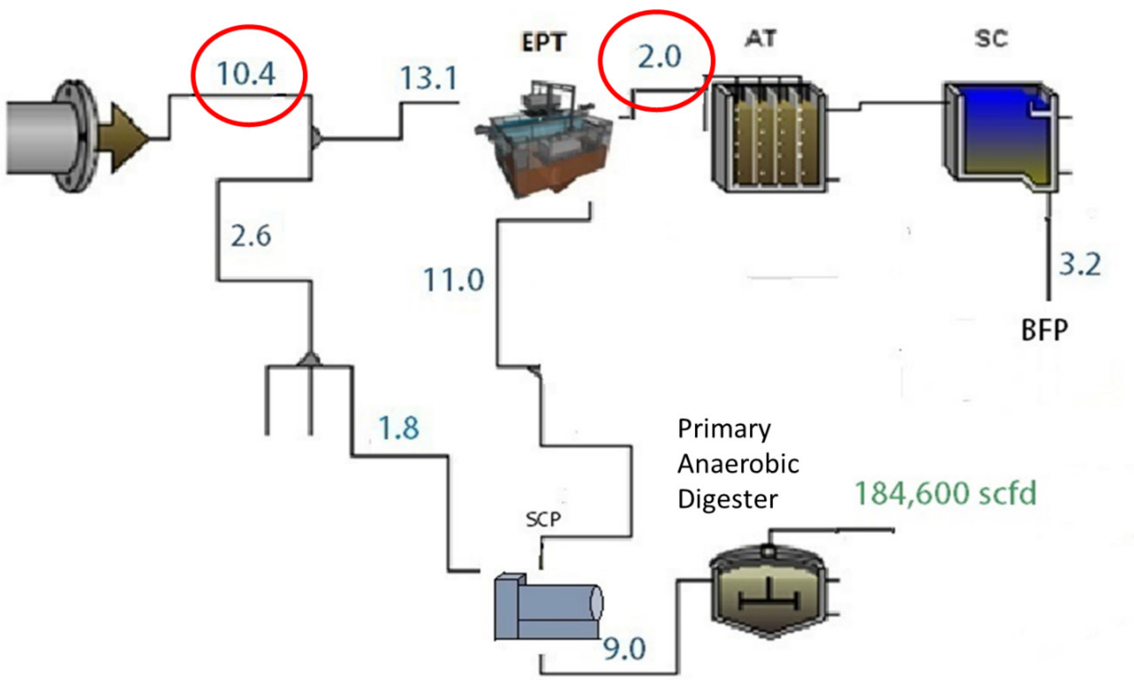
The impact of installing organics harvesting at full-scale was determined using pilot test results and the calculated mass balance of the existing system as follows.

7.1.1 Future Mass Balance

The incorporation of the OH and SCP into the IAWWTF produces a new process schematic, shown in Figure 43, for the following reasons:

- The OH followed by activated sludge may remove an adequate amount of phosphorus that the operation of the Actiflo would be greatly reduced to achieve the plant's target TP effluent level. Actiflo removes 0.86 MGD and approximately 470 lb/day of VSS that is returned to the head of the plant.
- The OH reduces primary sludge pumping due to higher solids concentration.
- The WAS is known to have a lower methane yield than primary and solid waste. To provide capacity in the primary digester for these two feedstock streams, the WAS may be diverted to the secondary digester. The SCP followed by a mechanical thickener would treat only OH primary sludge and grit, thus reducing flow to the existing gravity thickener. The existing gravity thickener would continue to thicken WAS and Actiflo backwash.

Figure 43. Mass Balance of Volatile Solids with the OH and SCPs



The documented performance of the pilot OH and SCP was applied to IAWWTF plant at an average daily flow of 6.4 MGD. The average percent removal rate and VSS concentration for the demonstration period were used. The projected side streams returned to the OH were incorporated into this mass balance.

As shown in Figure 43, for the demonstration period, the OH influent VSS was calculated to be 10,400 lb/day with an OH effluent being 2,000 lb/day for a removal rate of 81% versus IAWWTF's current performance of 16% removal. The OH removal rate of 81% versus 85% (pilot results) is due to the side streams not being accounted for in the influent VSS value of 10,400 lb/day. The WAS is directed to the BFP and is a lower volume, approximately one-third less VS entering the aeration tanks. The OH primary sludge is the only VS going to the SCP and then to the primary digester. The increase in methane production is due to greater VS destruction and a higher methane yield per pound of VS.

Addition detail on the Historical and Future Mass Balances can be found in Appendix F.

7.2 Primary Treatment

IAWWTF has two rectangular primary clarifiers. Each clarifier is 80-ft wide by 105-ft long by 13.5-ft side water depth. Each clarifier has four flight and chain sludge removal mechanisms that move sludge to the inlet end of the clarifier. Two cross conveyors in each clarifier then move the collected sludge and grit to a hopper where it is pumped to grit cyclones and then to a gravity sludge thickener.

As previously noted, there was an internal process upset and several plant upgrades that affected the primary clarifier effluent values during the demonstration period. Sample data during the demonstration period shows multiple days of higher primary effluent values than influent for all measured parameters due to the side streams returned to the head of the primary clarifiers.

Ferrous chloride is added to the existing primary clarifiers to reduce odors. Odors have not been an issue with the OH because the organics remain below the surface of the liquid; are pumped to the SCP, which is enclosed and operates under pressure; and then are discharged to a zero access gravity belt thickener, also enclosed and under a low negative pressure. This process allows odors to be contained and economically treated as the volume of air to be treated is small. The location of the proposed upgrade is near a public market so the tanks may be covered.

Ferric chloride ($FeCl_3$) and a polymer were added to the influent of the pilot OH and will be added to the full- scale unit to increase the capture rates of TP, TSS, and BOD. The addition of $FeCl_3$ to the OH is expected to allow the reduction in the operation of the Actiflo while still meeting the discharge limit. This reduces the sludge return and chemical use by the Actiflo unit.

The impacts of reduced BOD going to the existing aeration tanks reduces the number of tanks required to be operational, reduces the aeration energy required to convert BOD to CO_2 and biomass, thus reducing CO_2 emissions and biomass from the activated sludge process. This process also reduces the return activated sludge (RAS) pumped to the head of the aeration tanks. These aspects will be discussed in more detail in Section 7.

Table 9 shows that the sludge removal rate of the OH was 227 GPD per 13,200 GPD of influent, or 1.7% of the influent flow. The existing IAWWTF has a primary wasting rate of 0.43 MGD per 6.4 MGD of influent flow to the primary clarifiers or 6.7%. The high sludge withdrawal volume for IAWWTF is because the primary clarifiers also serve to remove grit. There is also the return of 2.34 MGD from the thickener, 0.018 MGD from the belt press, and 0.04 MGD from the secondary digester to the head of the existing primary clarifiers. With the installation of the OH, the sludge volume and liquids recirculated within the plant are projected to be reduced by up to 4 MGD, resulting in further energy savings.

The IAWWTF performs its grit removal on the primary sludge captured in its primary clarifiers. This diluted degritted primary sludge is then directed to the existing thickener and a significant portion returns to the head of the primary clarifier via the thickener overflow. Incorporation of the OH and SCP eliminates the recycled flow associated with grit washing to the head of the primary clarifier as this grit is removed and dewatered in the solids cake from the SCP.

The reduction of TP and BOD in the OH can be controlled between 50 to 70+ % removal by adjustments in the operating depth in the OH and the chemical dosing rate, thus allowing the operator greater flexibility.

The OH removes 25% of the TKN and 67% of the BOD, affecting the bacterial population ratio between heterotrophs and nitrifiers.

The most important aspect of this demonstration is the significant removal difference of VSS between the existing primary clarifiers (11%) and the OH (85%). The BMP and pilot digesters both confirmed higher methane yield from the primary VS than the VS from the WAS. This yield would be a major contributor to the shift from energy consumption to energy generation.

Table 9. Comparison of the Existing IAWWTF Primary Clarifiers and the OH

Parameter	IAWWTF Historical	IAWWTF Demo[c]	OH Demo[a,d]
Influent Flow	6.4 MGD	6.14 MGD	13,200 GPD
SOR (GPD/sq. ft.)	380	760	274
Primary Sludge Withdrawal Vol.	0.43 MGD	NRV[b]	227 GPD
Primary Sludge Pumping / Influent Flow	6.7 %		1.7 %
Primary Sludge TSS (mg/L)	8,132	NRV[b]	10,813
Primary Sludge VS%	56 % (4,554 mg/L)	NRV[b]	83% (8,975 mg/L)
Influent BOD (mg/L)	151	171	171
Primary Effluent BOD (mg/L)	107	180	55
Removal Rate	29%	-2%	67%
Influent TSS (mg/L)	152	237	237
Primary Effluent TSS (mg/L)	112	253	36
Removal Rate	26%	-1%	84%
Influent VSS (%TSS)	90% (137 mg/L)	195	195
Primary Effluent VSS (%TSS)	86% (96 mg/L)	214	27
Removal Rate	30%	-20%	85%
Influent TP (mg/l)	3.7	3.6	3.6
Primary Effluent TP (mg/L)	NRV[b]	3.1	0.9
Removal Rate		15%	72%
Influent TKN (mg/L)	28	29	28
Primary Effluent TKN (mg/L)	NRV[b]	34	21
Removal Rate		-16%	26%
Influent COD (mg/L)	NRV[b]	361	361
Primary Effluent COD (mg/L)	NRV[b]	337	127
Removal Rate		9%	62%
Influent SBOD (mg/L)	NRV[b]	35	35
Primary Effluent SBOD (mg/L)	NRV[b]	40	26
Removal Rate		1%	25%

[a] The OH influent flow was restricted to the amount of sludge that could be captured over a 24-hour period. Pilot limit is 1,000 GPD/ Sq. Ft. Full-scale plants are expected to have a higher surface overflow rate (SOR) . Also, full-scale removal performance is expected to be similar or better as the effluent will be a minimum of 5 ft away from the sludge blanket, versus 1.8 f. in the pilot.

[b] No Recorded Values (NRV) by IAWWTF

[c] Primary clarifier samples collected during the 80:0.25 OH demonstration period

[d] OH influent concentration, effluent concentration and removal rates used were that of the optimized dose of 80:0.25 ($FeCl_3$: polymer doses in mg/L)

7.3 Aeration

7.3.1 Plant-Wide Impacts

A primary focus of the project at the IAWWTF was demonstrating that the majority of wastewater organics could be removed by the OH technology at the primary treatment stage and that removal of organics at this stage should lead to reduced energy consumption in the aeration system. IAWWTF utilizes an activated sludge process to convert BOD to biomass and CO_2. Many studies have documented that aeration energy to support the suspended biomass is the largest energy consumer in the wastewater treatment process.

The existing secondary treatment process consists of four aeration tanks, each 41-ft wide by 100-ft long with a side water depth of 16.4 ft providing a volume of approximately 0.5 million gallons each. Three aeration tanks, each having new fine bubble diffusers, were in operation during the demonstration period. Table 10 describes operating parameters used by IAWWTF to convert the BOD_5 received in the primary clarifier effluent to CO_2 and biomass.

To keep the secondary clarifiers performance similar in the comparison of the OH to the existing primary clarifiers, the number of aeration tanks in operation were reduced while maintaining the F:M (food-to-microorganism) ratio within the acceptable range.

Table 10. Impact of BOD Reduction on Biological Activities in Aeration Tanks Using Historical IAWWTF Data in Table 9 Criteria

Primary Clarifier	Inf Flow MGD	BOD5 Inf (mg/L)	BOD5 Primary Eff (mg/L)	BOD5 Reduction	Lbs./Day BOD5	Aeration Tanks in Operation	F:M ratio	MLSS (mg/L)	MLSS lb/day
Existing	6.4	151	107	29%	5,711	3	0.30	1,513	19,000
OH	6.4	151	50	67%	2,669	2	0.21	1,515	12,700

To maintain the MLSS (mixed liquor suspended solids) concentration, the number of tanks in operation was reduced from three to two. The F:M ratio was reduced from 0.3 to 0.21. The recommended design values for this type of activated sludge process are an F:M ratio from 0.2 to 0.5 and the MLSS from 1,000 to 3,000 mg/L. In the previous comparison, the F:M ratio and MLSS are within acceptable design parameters.

The hydraulic retention time (HRT) with existing and projected side streams included, remains about the same with the existing, or three tanks operating, being 2.6 hr (1.5 million gallons/13.7 MGD); and the OH 2.3 hr (1.0 million gallons/10.4 MGD) with two tanks in operation. The HRT is not expected to be an issue as the solids entering the aeration tanks from the OH will be less than 50 micrometers in size. These small organic solids provide greater surface area and thus increase the biodegradation rate. High wet weather flows exceeding the OH capacity would be diverted to the existing primary clarifiers for retention or processing and delivered to the secondary aeration process.

The ability to remove enough BOD to take an aeration tank (or tanks) offline provides greater energy reduction by turning off a blower, versus turning down the speed. The type of aeration blower used at the facility can place limits on the minimum turndown (reduced RPMs). Reducing a blower's speed may also move the blower's performance away from its optimum operating efficiency.

The ability to reduce the number of aeration tanks provides IAWWTF with operational flexibility. In the case of IAWWTF, it would lessen future need for a capital upgrade to repair the aged aeration tanks which have exceeded their expected life and are in need of repair. The need to repair only two or three of the tanks provides reduced capital costs and improves the construction sequence by being able to repair tanks while remaining in operation.

7.3.2 Energy Impact

The total average energy consumption of the IAWWTF is approximately 9,100 kWh/day. According to submetering results from a previous NYSERDA study[5], aeration accounted for 48% of the plant's total energy consumption. Of the aeration energy consumption, 72% or 3,100 kWh/day is for the removal of BOD with the remainder of the energy consumption going to nitrification.

A metric of 0.55 kWh/lb BOD removed was established to calculate the aeration energy consumption values. The 0.55 kwh/lb BOD removed in secondary treatment comes from a number of sources, realizing that the plant's energy utilization has changed little over the past decade. In 2013-2014, new diffusers were installed, but automated DO control and new blowers were not installed/utilized until the

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5 Malcolm Pernie, 2005, "Municipal Wastewater Treatment Plant Energy Evaluation for Ithaca Area Wastewater Treatment Facility, NYSERDA

NYSERDA demonstration was near its end. The energy metric was calculated from a 2005 NYSERDA submetering report, 2009 analysis of the aeration system blowers, and 2013-2014 plant operating data. The submetering report indicated the electric energy usage for aeration blowers was 1.463 GWh/year and return activated sludge (RAS) pumping was 0.196 gWh/yr. WAS pumping usage was not quantified in the study. The secondary treatment usage amounted to 4,548 kWh/day.

The aeration blower analysis showed that 72% of the air supply was used for BOD removal and 28% for nitrification. Thus the amount of aeration energy usage for BOD removal was calculated as 3,275 kWh/day.

The 2013-2014 data showed that 5,955 lb/day BOD was removed in secondary treatment. Therefore, the amount of energy to remove BOD in secondary treatment is calculated as 3,275/5,955 or 0.55 kWh/lb BOD removed.

Using the average BOD removal rate of 67% from the 24-hour composite sampling of the OH pilot, it is expected the OH would reduce aeration energy consumption by 52% if implemented at full scale. The data and calculations are shown in Table 11. These BOD removal and lb/day calculations were performed using the BOD concentration of 151 mg/L from the IAWWTF historical data. If the influent concentration of 171 mg/L measured during the demonstration period was used, it is expected that the aeration energy savings would increase to approximately 62%.

Table 11. Calculated Aeration Energy Impact Using IAWWTF Historical Data

Parameter	Existing	W/ OH
BOD removal in aeration (lb/day)	5,711	2,669
Air required for BOD load (scfm)	2,090	1,040
kWh/lb BOD removed	0.55	0.55
Aeration Energy Consumption (kWh/day)	3,100	1,500
Annual Aeration Energy Consumption ($/yr)[at 9.5 cents/kW]	$108,000	$52,000

Frequently asked questions from the Project Advisory Committee:

- **Will the biology in the aeration process have enough BOD to effectively treat the wastewater for nutrient removal?**
  It is anticipated that with a reduced organic load to aeration, the microbial population will shift toward a greater population of nitrifying bacteria and fewer carbonaceous bacteria. Treatment effectiveness may be maintained with a different bacterial population. The IAWWTF does not have effluent limits for nitrogen, neither total nor ammonia; therefore, biological nutrient removal is not practiced or necessary at this facility. However, because many facilities require BNR, additional research on the OH's effect on nutrient removal is warranted in future studies.

- **Can the IAWWTF turn down or turn off its blowers or reduce the number of aeration basins in operation enough to accommodate the lower BOD influent the aeration will be receiving?**
  Yes. Section 7.3.1 shows indicates an opportunity for one aeration tank to be taken offline and still provide the same BOD reduction, as the F: M ratio and HRT are similar.

7.4 Digestion

The IAWWTF currently operates two 1.4 million-gallon anaerobic digesters to both stabilize sludge and generate heat and power for the facility. Operated in series, the primary anaerobic digester produces the majority of the biogas, while the secondary anaerobic digester provides solids storage and thickening of the primary digester biosolids along with additional biogas capture. Data from the OH pilot and pilot digesters were used to calculate the expected impact on the anaerobic digesters in terms of VS loaded, destroyed, and methane generation.

In the scenario in which the OH and SCP are installed in conjunction, the IAWWTF primary anaerobic digester would only receive OH sludge. Unlike the scenario using the current thickener with the OH – which involved feeding a blended primary and secondary sludge to the digester – the SCP scenario allows use of the OH sludge destructive yield rate (previously described in Section 5.4.1) of 29.3 scf CH_4/lb VS destroyed, because only OH will be fed to the digester.

The projected VS destruction of the OH sludge at full scale in the SCP scenario was scaled from pilot digester results of the Ithaca thickened sludge digester PD-1 (the control), compared to full-scale experience. Higher VS destruction occurred at the pilot scale of OH sludge than with the Ithaca thickened sludge. At full scale, based on the pilot result, there would be higher degradation of OH sludge expected than the facility experiences now. PD-1 achieved 41% VS destruction on average in comparison to the

IAWWTF full-scale digester's percent destruction of 57%. This scale up ratio was then applied to the 51% destruction rate in the OH pilot digester (PD-3), projecting that 70% VS destruction of OH sludge would be achieved at the full-scale detention time. Further research is required to determine if this high of a destruction rate with municipal wastes would have unintended consequences, such as higher digester ammonia or phosphorus concentrations. This difference may or may not be not be significant.

Applying the projected 70% VS destruction and 29.3 scf/lb VS destroyed of the OH sludge to the 9,100 lb/day VS loading to the primary digester, it is expected that the IAWWTF will generate 184,600 scfd CH_4. This is a 520% increase in methane production from what would be observed by digesting solely the facility's primary sludge, and an increase of 320% in total plant methane production compared to existing conditions.

Table 12. Calculated Digestion Impact

Parameter	Existing IAWWTF Historical	OH with Current Thickener	OH with SCP
Volatile solids loading (lb/day)	13,000	13,600	9,000
Volatile solids destroyed (lb/day)	7,400	8,400	6,300
Methane generation (cu. ft./day)	57,100	105,600	184,600
Micro turbine generation potential (kWh)	2,500	4,600	8,200

Frequently asked questions from the Project Advisory Committee:

- **With the additional methane generation, will additional microturbines be required?**
  With the additional methane generation the IAWWTF should satisfy their current onsite energy demands. Once the facility's onsite energy needs were satisfied, the facility could install the necessary additional equipment to convert any excess biogas to compressed natural gas (CNG) and construct a fueling station to fuel municipal vehicles such as the city buses.

- **Will the relative capacity of the digester be increased based on the increased biodegradability of the ClearCove OH sludge and reduction in trash or solid particles greater than the SCP screen opening size?**
  It is expected that the solids retention time (SRT) of the digesters will be decreased, which would correspond to an increase in the relative capacity of the digesters. ClearCove sludge is more biodegradable than conventionally-produced sludges, due to smaller organic particle size and absence of grit/trash. The pilot digester project validated that the OH sludge could be fed to the digester at twice the VS loading rate (as was fed to PD-2B as described in Section 5) and meet the same VS destruction rate as the other pilot digesters fed at the normal rate. This finding supports that the sludge is more rapidly biodegradable and, because it can be fed at a higher rate, it reduces the SRT and increases the relative capacity of the digester. In addition, during the operation of the pilot digesters, the IAWWTF thickened and primary sludge had to be screened due to the presence of inorganic solids and grit that would have clogged the system. In Ithaca's full scale process these materials make their way to the digester, take up capacity and, eventually, the digester would have to be shut down and cleaned out. The SCP unit removes this trash, resulting in trash and grit free OH sludge to be fed to the digester.
- **What operation issues may arise from a higher primary/secondary sludge ratio being fed to the digester?**
  No operational issues are projected from the increased ratio of primary to secondary sludge being fed to the digester. The IAWWTF opened its new food waste receiving facility during its demonstration and received substrates from the surrounding community and an increase in trucked-in residuals as a result. The staff made adjustments to the previous digester feed procedures to account for this different and increased substrate. The OH sludge/substrate has less variability than the trucked-in waste, so the acclamation of the biology should be more stable.
- **What is the optimum sludge thickness (% solids), and what can be achieved at the IAWWTF?**
  During this demonstration project, impromptu tests using belt press fabric in a frame, placing the SCP sludge in the frame, and gently pressing the sludge, produced a solids content in the 5-7% range with low COD and solids content in the pressate. In the full-scale system, the OH sludge will be fed to the SCP, discharged on to a gravity belt thickener and immediately delivered to the digester. The solids content of the primary sludge is expected to be in the 4% range.

7.5 Grit and Screening Impact

The IAWWTF currently has a 1.5-inch mechanical bar screen in the headworks building of the facility. If the OH and SCP were installed at full scale, this mechanical bar screen would no longer be used as this function would be performed in the OH system. Having grit removal and screening ahead of the OH is acceptable as well.

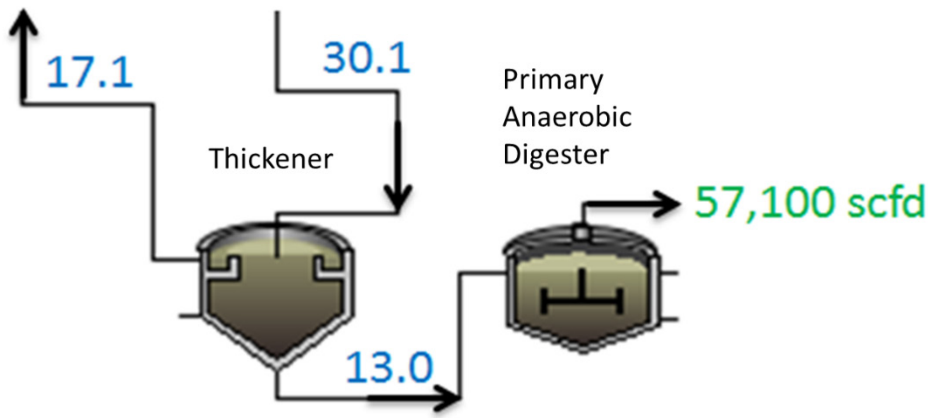
The current method of grit removal at the IAWWTF is to send the primary sludge captured in its primary clarifiers to a grit cyclone resulting in very dilute primary sludge being sent to the thickener. This results in significant amounts of liquid laden with solids and organics being returned to the primary clarifier. During the demonstration, thickening and screening of IAWWTF primary sludge was performed to increase the percent solids content from less than 0.5% TS to 1.9% TS and to remove the remaining grit and gross solids in the sludge that would otherwise clog the pilot digester system. At full scale, this remaining grit and trash in the sludge occupies space in the digester and reduces its capacity over time. In addition, the dilution of the primary sludge results in significantly more water being sent to the gravity thickener.

When installed at full scale, the OH and SCP would remove the need for the grit cyclones. The sludge and grit captured in the OH is sent through the SCP, which separates the grit from the sludge; shears the encased organics; compacts the hair, fibers and large solids (principally inorganic). and thickens the sludge. This removes the problem of the dilute primary sludge being sent to the thickener and prevents the grit and inorganics from making their way into the digester and taking up capacity. Another minor advantage is the blending of the sludge prior to addition into the digester means there is little conversion of the high VSS and SBOD into biomass and CO_2 before entering the digester.

7.6 Volatile Solids Processing

The majority of sludge currently produced at the IAWWTF is comprised of 70+% WAS and 30% primary sludge, with a small amount coming from the Actiflo process which is expected to be low in VS% and methane value. The sludge is combined and thickened prior to feeding to the digesters. The capture of thickened solids in the gravity thickeners is less than 50%, which means that only 13,000 lb/day VS is sent to the primary digester, while 17,100 lb/day VS is returned to primary treatment, as illustrated in Figure 44.

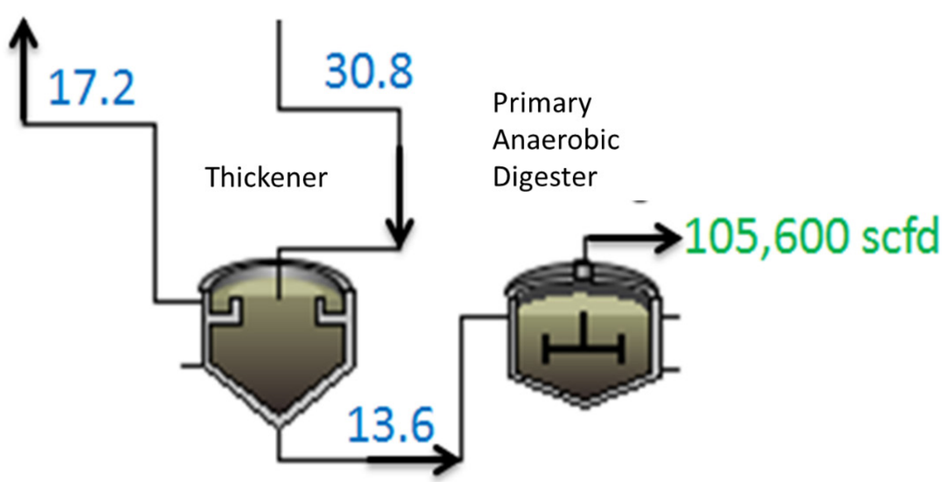
Figure 44. IAWWTF Current Sludge Processing (IAWWTF Historical)



As the ClearCove OH technology captures more organics and solids in the primary treatment stage, the ratio of primary to waste activated sludge produced will shift to 5:1 based on the demonstration results. However, the increase in VS loading to the primary digester is only predicted to be 600 lb/day more, as shown in Figure 45. With the greater proportion of primary sludge, the increased methane production is predicted to be 100,000 scfd, a 75% increase.

The projected IAWWTF upgrade using the OH and SCP will not send primary sludge to the existing gravity thickener. Figure 45 is for comparative purposes for only if the OH were installed and the gravity thickener remained.

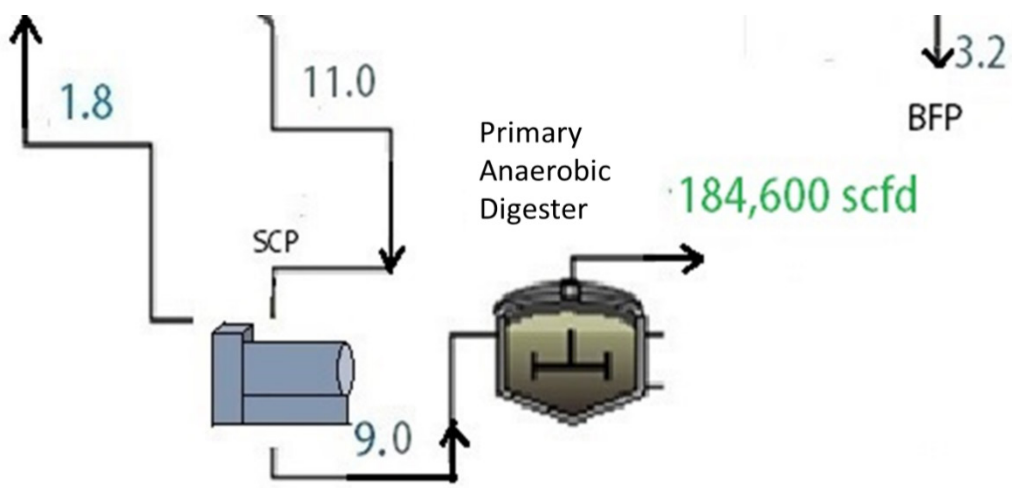
Figure 45. Sludge Processing with OH and Current Thickener



The OH sludge is expected to have a higher TS concentration as primary sludge typically thickens to a higher solids concentration because it is free water versus the higher internal liquid content of WAS. The higher sludge concentration would increase the detention time in the digester and facilitate higher VS destruction rates.

The proposed upgrade of the IAWWTF consists of installing the OH and SCP technologies. The sludge processing operation (cleaning, particle size classification, and thickening) of the facility would result in an increased HRT in primary digester. In addition, the recirculation of 9,100 lb/day of VS to the head of the plant would be reduced to a projected 1,800 lb/day. The plants 3,200 lb/day of VS in the WAS would no longer be blended with the primary sludge. The WAS may instead be sent to the BFP feed. The primary digester would only receive OH sludge processed by the SCP lowering the lb/day of VS and flow returned to the head of the plant (Figure 46).

Figure 46. Sludge Processing with OH and SCP



Using the 24-hour composite sample data of the influent and OH effluent, a mass balance was performed to determine how much BOD and primary sludge will be captured in ClearCove OH and how much BOD will go forward to, in turn, end up as secondary sludge. Table 13 provides the calculations.

Table 13. Calculated Volatile Solids Processing Impact

Parameter	Existinga	OH with SCPb
Primary sludge generation (lb/day)	20,100	11,100
WAS + Actiflo backwash generation (lb/day)	10,000	3,200
Total Sludge Production (Dry lb/day)	30,100	14,300

[a] Is based on IAWWTF historical data including existing recirculation rates

[b] Is based on OH Demonstration period with projected recirculation rates

Frequently asked questions from the Project Advisory Committee:

- **How will the sludge processing of the IAWWTF be affected by a ClearCove installation?** A similar amount of thickened sludge is expected to be sent to primary anaerobic digestion. Because this thickened sludge contains a higher proportion of primary solids, greater VS destruction is expected during anaerobic digestion. The pilot results showed an increase in VS destroyed from 41% with the thickened sludge, to 51% with the enhanced primary sludge. A higher VS destruction means fewer solids in the digestate going to dewatering and a lower loading rate to (or shorter operating time of) the belt filter press (BFP). Chemical precipitants from the dosage of ferric chloride at the front of the plant have not been researched but would be of merit for future studies. The total iron addition will be similar or less than the current dosage, so the amount of inorganic solids generated is expected to be similar or less than the facility sees now.
- **Will the SCP increase the amount of trash sent to the landfill?** The IAWWTF has a 1.5-inch mechanical bar rack that discharges into a dumpster, grit is discharged into another dumpster, and the biological solids are dewatered on a belt press. These solids are all currently disposed of at a landfill. The OH captures all solids greater than 50-micrometers and directs those solids to the SCP for processing. Two separate streams come from the SCP: one is a solids cake that is comprised mostly of hair, fibers, plastic and other trash; and the other stream is a conditioned sludge which is free of trash. The solids content of the SCP sludge cake is expected to be in the 30-40% solids range, thus having less volume than the non-compacted screenings currently captured by the mechanical bar rack. This solids cake from the SCP would be directed to the landfill because it has little to no value when fed to the anaerobic digester. The conditioned sludge exiting the SCP thickener will be directed into the anaerobic digester for volatile destruction and then to the belt press for dewatering of the remaining solids. This digested and dewatered post-digestion sludge would also be directed to the landfill just as the IAWWTF currently does. As stated earlier, the volatile destruction is expected to increase from 41% to 51%, or 20% greater conversion. For these reasons, the sludge being moved to the landfill is expected to decrease.

- **How will the ClearCove OH impact the Actiflo unit?**
  The IAWWTF currently has an average of 2.6mg/L total phosphorus in its primary effluent. With OH, it is predicted that the primary effluent TP concentration will be 0.9 mg/L, a 72% reduction. An estimate for the TP concentration in the secondary effluent going to the Actiflo has not been made. For tertiary treatment performed by the Actiflo system, a lower TP concentration means less addition of chemical and less sludge. Currently, this low gas value sludge is being returned to the thickener and then primary digester. The reduction of this sludge will reduce the recirculation of solid laden liquid through the plant. Therefore, OH is expected to reduce the chemical dose required for satisfactory Actiflo operation.

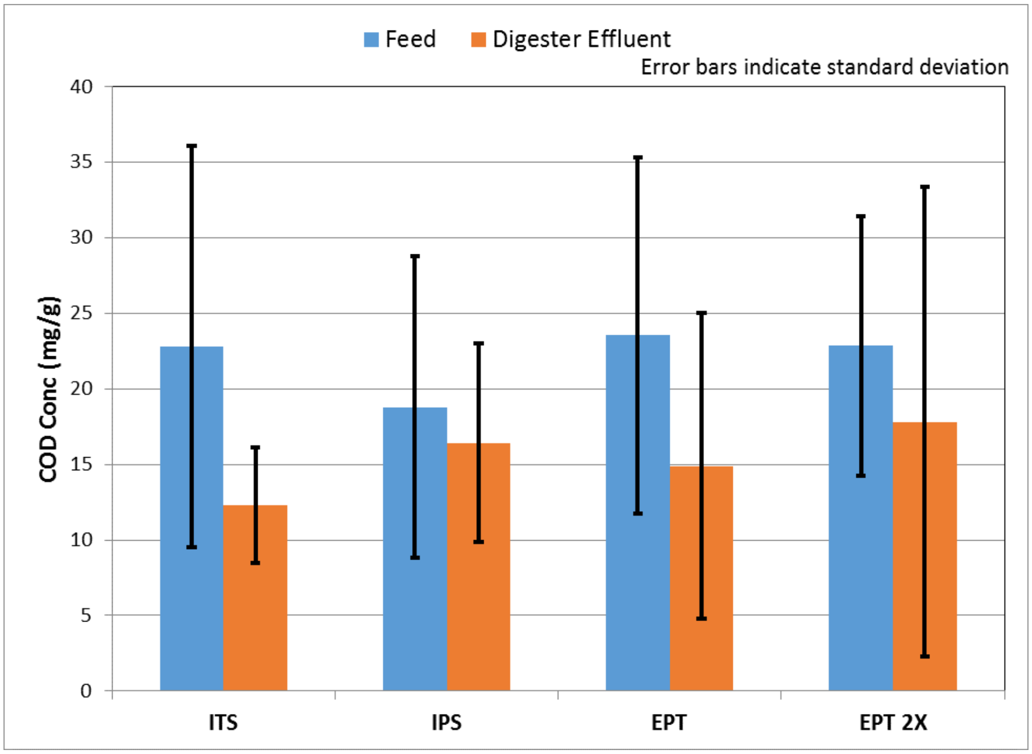
7.7 Return Flows

The internal recirculation of solid laden liquids within the IAWWTF will be reduced by a projected 4.0 MGD in these following areas:

- The WAS pumping will be reduced as the amount of biomass required to treat the lower influent BOD as the pounds of biomass drops from a projected 19,000 to 12,700 lb/day.
- The existing primary clarifiers continually pump the captured grit and sludge to the grit cyclones at a rate of 0.43 MGD. The OH/SCP has a projected sludge removal rate of 0.11 MGD due to higher concentrations and no grit washing for a reduction of 0.32 MGD.
- The 0.72 MGD of primary effluent pumped to wash grit will be significantly reduced by the use of the SCP.
- The 0.86 MGD Actiflo sludge return is expected to be reduced as the OH and biological activity are projected to adequately reduce the TP to allow for the Actiflo operation to be reduced.

Anaerobic digestion breaks down solids and converts the carbon in the solids to methane and carbon dioxide. Nitrogen and phosphorus contained in the digested solids are typically released in a soluble form and end up in the filtrate/centrate from dewatering, which is returned to the head of the WWTF. During the demonstration, the soluble components of the feed sludge and pilot digester contents (which would be the same composition as the filtrate/centrate from dewatering) were analyzed for COD, ammonia-N and ortho-phosphate to predict the impact of digestion releases on the quality of the return flow from dewatering. The average total COD concentrations for all digested sludge showed a drop after digestion, as shown in Figure 47.

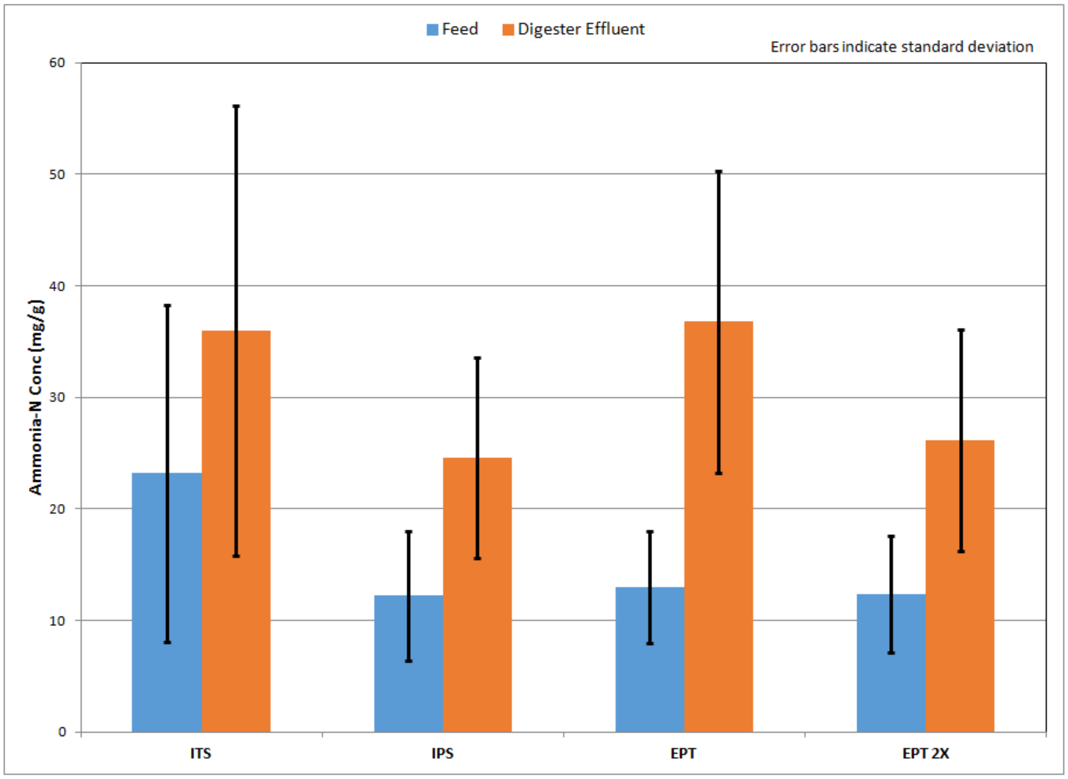
Figure 47. COD Concentrations in Pilot Digester Feed and Digestate



There does not appear to be a difference in COD removal between all the pilot digesters, so the impact of the return from OH digested sludge is expected to be minimal.

The fate of ammonia in the digesters is different. Figure 48 shows the ammonia concentrations in the feed and digester contents, which has the same soluble composition as the filtrate from dewatering. Ammonia is only in the soluble portion of these samples.

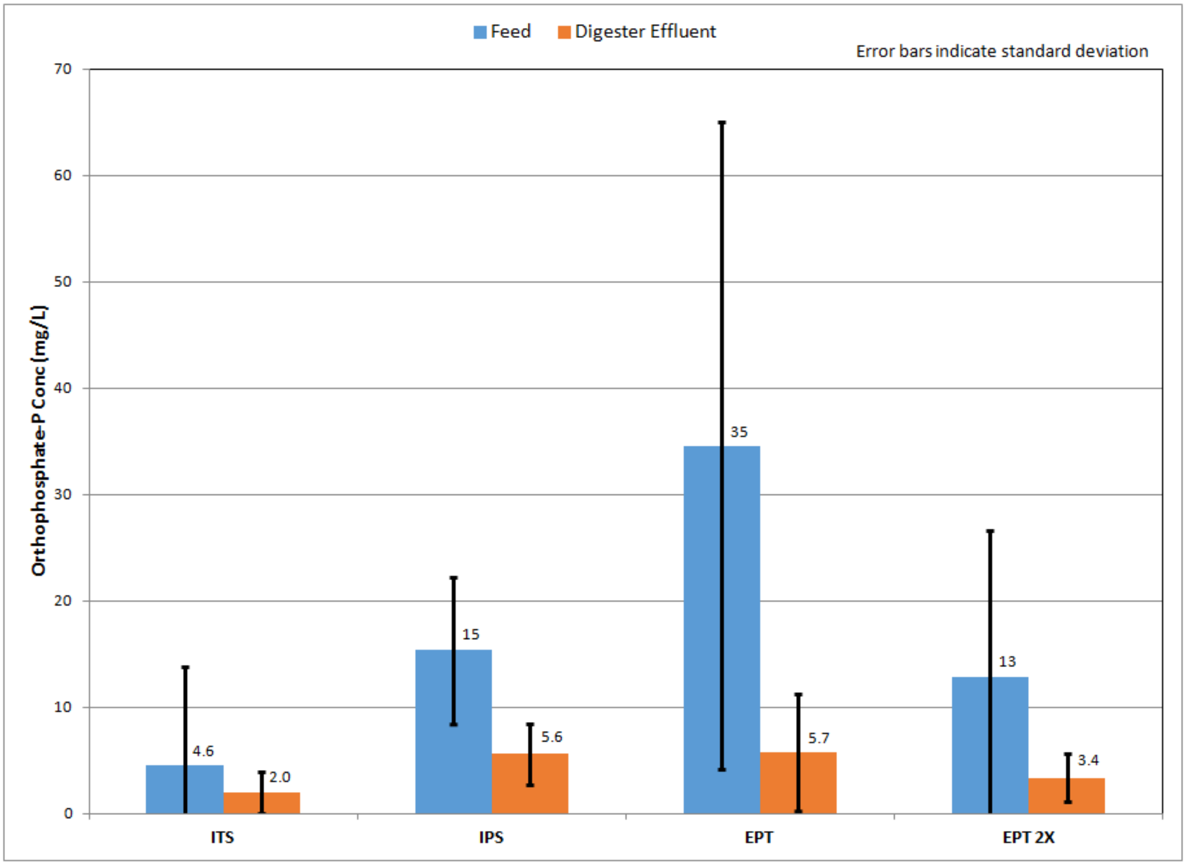
Figure 48. Ammonia Concentrations in Pilot Digester Feed and Digestate



The digestion of all three sludges released ammonia, as one would expect, and the higher loaded digester (OH 2X) showed a similar release as the lower loaded units. The amount of ammonia in the feed was lower in the IAWWTF and OH primary sludge than the IAWWTF thickened sludge. The ammonia in the digester effluents was similar for all pilot digesters. The predicted impact of ammonia release during digestion was no different from current concentrations historically released by IAWWTF digester overflow. Even though the OH sludge had higher destruction rates, the ammonia release was statistically similar to the release from digestion of thickened sludge.

The fate of phosphorus in the digesters was different than expected. Figure 49 shows the orthophosphate phosphorus concentrations in the digester feeds and effluent.

Figure 49. Orthophosphate Concentrations in Pilot Digester Feed and Digestate



The data indicate a reduction in soluble phosphorus (ortho-P) across each digester. With VS destruction in the digesters, one would expect higher ortho-P concentrations in the digester effluent than in the feed. This observed decrease may be due to high feed concentrations. One explanation for higher ortho-P concentrations in the pilot feeds could be that the sludge collection method and the detention time in the pilot feed tank facilitated some hydrolysis of solids and release of phosphorus prior to digestion.

In Figure 49, the thickened sludge (ITS) digester effluent had an average ortho-P concentration of 2.0 mg/L, which was lower than the 3.5 to 5.7 mg/L concentrations from the digester effluents of the primary sludge (IPS and OH). However, the concentrations were statistically similar with 95% confidence as noted by the overlapping ranges in the error bars in Figure 49. An estimate of the impact from return of filtrate/centrate after dewatering the sludge is:

- ITS digested sludge filtrate ortho-P is 0.3 lb/day (based on 18,000 GPD and 2 mg/L).
- IPS digested sludge filtrate ortho-P is 0.8 lb/day (based on 18,000 GPD and 5.6 mg/L).
- OH digested sludge filtrate ortho-P is 0.9 lb/day (based on 18,000 GPD and 5.7 mg/L).

The IAWWTF influent ortho-P load is approximately 100 lb/day. The small amount that recycles in the return from sludge dewatering either currently or in the future with OH is a nonsignificant increase and will have a very minor impact to the IAWWTF.

7.8 Chemical Usage

The IAWWTF currently injects ferrous chloride in the primary clarifier influent for odor control and ferric chloride is used in tertiary treatment for phosphorus removal. The ClearCove technology also uses chemicals to coagulate and flocculate solids so as to accelerate and enhance settling. The chemicals are dosed into the wastewater as they enter the OH tank. The ClearCove process has a full Supervisory Control and Data Acquisition (SCADA) system to continuously track chemical usage and dose. Chemical use under the plants existing operations and full-scale implementation of the ClearCove OH process are compared as follows.

Frequently asked questions from the Project Advisory Committee:

- **Would the ClearCove OH system increase or decrease the chemical costs at the IAWWTF?**
  The IAWWTF currently doses 50-100 GPD on average of ferrous chloride at the headworks of its plant for odor control, and 400-500 GPD of ferric chloride ($FeCl_3$) on average in the Actiflo at the end of the treatment process for phosphorus polishing. The $FeCl_3$ dosing in the Actiflo process can reach up to 700 GPD at peak dosing. At the IAWWTF, average dosing rate spent is approximately $164,250/year on $FeCl_3$ alone. At the IAWWTF, with the average daily flow of 6.4 MGD, and the dosing of 80 mg/L of $FeCl_3$ and 0.25 mg/L of anionic polymer, the OH will use 400 GPD of $FeCl_3$ and 1.35 GPD of polymer for an estimated annual chemical cost of $141,000. Due to the OH being at the headworks of the facility, this may negate the need for the ferrous chloride addition that currently takes place, however, this could not be validated through this pilot demonstration. At OH dosing of 50 mg/L $FeCl_3$ and 1.0 mg/L anionic polymer, the OH uses 230 GPD of $FeCl_3$ and 5.4 GPD of polymer with an estimated annual chemical cost of $108,000. The same potential benefit of eliminating the headworks addition of ferrous chloride could be realized at this dosing rate as well. If the OH was installed at full scale, the chemical dosage that was being consumed in the Actiflo process at the back end of the plant would be shifted to the front of the plant.

- **How does the ClearCove Organics Harvester (OH) technology compare to Chemically Enhanced Primary Treatment (CEPT)?**
  Chemically Enhanced Primary Treatment (CEPT) involves the addition of chemicals in the form of coagulants and polymers to conventional primary clarification to promote settling of solids. CEPT has grown to include ballasted flocculation and contact clarification products. CEPT can be as simple as dosing chemicals in a traditional primary process to more sophisticated primary complimentary applications. CEPT technologies can be implemented at various points in the organics removal process and flow rates of 3000-6,000 Gals / Sq. Ft. surface overflow rate (SOR) to treat diluted sewage within the same primary clarifier footprint is not unusual. Typical clarifiers are 1,000 to 1,500 Gals / Sq. Ft. surface overflow rate.
  The Organics Harvester (OH) as delivered by ClearCove is a flexible, scalable, multiple operation, integrated technology focused on energy impact by highest value organics harvesting, sludge cleaning, sludge thickening with enhancement for anaerobic digestion and full headwork's replacement. OH provides dedicated removal of grit, hair, fiber, floatables, FOG and inorganics. OH has the ability to integrate chemically enhanced primary treatment as part of the solution or not. OH provides flow equalization and 50 micron fine screen filtration for optimized secondary performance. Through sludge cleaning and enhancement, can provide trash removal and solids classification with thickening for maximum anaerobic digestion "fuel" or bio methane potential. The system allows for fully automated primary operation.
  The OH is an integration of many headworks and plant processes, designed to optimize energy production, energy reduction and enable resource recovery for maximized economic impact on the plant.

  There are number of important distinctions that differentiate this OH from CEPT:

  - **Flow Range** – OH can be designed for peak flow rates operating for the purpose of organic capture and carbon diversion during peak, average, and dry flow periods. That said, the OH can be sized specifically for focused organics capture at average or dry flow rates while using the existing primaries to handle high flow diversion. The primary purpose of OH is to reduce organic loading on the secondary process, which corresponds to reduced aeration requirements in the secondary process and increased capture of organics with high biomethane potential that can be directly routed to the anaerobic digesters.
  - **Chemical Dosing** – OH can be operated as "physical" only or with chemical dosing targeted for maximum organic solids and nutrient harvesting for energy production and energy reduction benefits, tailored to the specific plant needs and requirements. With built in automation and sensing technology, the system can be programmed to automatically adjust based on diurnal flow patterns entering the plant, thus allowing for adjustments in minutes to the dosing rate and mix.

- **Flow Equalization** – A built in feature for the OH is flow equalization. Use of a minimum of two tanks and pumping into the system at maximum pumping rate to allow for complete stoppage of flow in one tank(s) for maximum solids settling time, as the other tanks(s) decant at a controlled rate, consistent rate to the secondary, allow for the secondary to receive a consistent load of organics for optimized biological processing and protecting downstream processes from high flows. The settling time is controlled through automation and sensing technology, thus allowing the system to automatically adjust settling time, any time, based on incoming flow patterns.
- **BOD Removal** – OH pilot results indicate 65+%. Expected removal range 50-80% average, dependent on mechanical versus chemical operation and wet vs. dry weather flows (7/24/365).
- **Grit Removal** – OH has an integrated specific grit removal chambers to allow for in-vessel classification of solids and removal of 100% of the grit and the classification of solids, both organic and inorganic. The Sludge Classifying Press, through two types of operations, removes all trash and inorganics and cleans and thickens the "sludge" going forward to the anaerobic digestion process.
- **FOG and Floatables** – **OH** uses a physical process to raise the water depth to a FOG and floatable removal trough that moves the inorganics to trash and FOG to digestion. The frequency is programmed into the automation and controls programming.
- **Microscreening – OH:** All effluent coming from the enhanced primary treatment is decanted through a non-fouling 50 micrometers set of screens, sized based on flow. This prevents any solid larger than 50 micrometers to flow into the secondary. In addition, 100% of the hair and fiber is removed, thus sending none to the secondary process.
- **Ballasting** – No ballasting is needed for the OH to enhance contact clarification and organic solids removal.
- **Chemical Mixing** – All mixing is performed via fluid dynamics within the OH tanks with no mechanical mixers.
- **Automation and Controls** – OH is flow based with five modes of operation, sludge pump controls, automatic operation and maintenance tracking and scheduling, report generation, historian, operator assistance package, COD sensors or programming, and SCP controls. The SCADA-based automation and controls is designed with triple redundancy to manage the entire plant impact on energy and biological demand.

7.9 Energy Considerations

It is expected that the plant energy balance would shift as a result of a full-scale ClearCove OH and SCP installation. Using information developed in the previous sections, the energy balance based on a full-scale installation was calculated and compared to the baseline energy balance. In calculating the new energy balance the following assumptions were made: the BOD loading to the secondary treatment process would decrease, WAS production would decrease, biogas generation would increase, internal recirculation pumping would decrease, and less sludge would require transportation for disposal. These implications are plant wide.

7.9.1 Energy Savings

The IAWWTF currently consumes 9,400 kWh/day or 3.3 GWh/year. Aeration accounts for approximately 48% of this energy consumption with 72% of the aeration energy consumed for the removal of BOD_5 or 3,275 kWh/day. If the OH was installed at full scale, it is anticipated that aeration energy consumption would be reduced to 1,500 kWh/day, which would reduce total plant energy consumption by 22% to approximately 7,385 kWh/day or 2.7 GWh/year. This energy reduction would save the facility approximately $56,000/year. The 2005 submetering report performed by NYSERDA that was used for many of the energy data in this report had deemed that WAS pumping was too small to measure. Thus, this information was not included in the energy savings calculation. A post-OH installation energy audit would be beneficial to understand the true energy saving impact of the technology.

7.9.2 Energy Production

Energy production calculations were performed to forecast the potential energy generation for the following scenarios previously described in this report:

- Current IAWWTF from Plant Residuals – The current conventional IAWWTF process.
- OH w/ IAWWTF Current Thickener – The OH installed with the IAWWTF's current thickener still in place.
- OH w/ SCP – The OH installed as well as the SCP in place of the IAWWTF gravity thickener. The SCP would provide the thickening as well as the conditioning of the sludge to provide an improved sludge to the anaerobic digester.

The IAWWTF currently produces 57,100 scf CH_4/day or 20,841,500 scf CH_4/year from plant residuals. This amount does not include biogas produced due to trucked in waste. This methane is converted to 2.2 gWh/year of electricity via microturbines with the facilities 35% gas to electricity conversion rate, or capacity factor, as detailed in the energy model in Appendix H. Under the current operation of the IAWWTF thickener, with current poor solids capture, the OH would increase the biogas production by 185% to 38,556,775 scf CH4/year, which correlates to 4 GWh/year, assuming the 35% efficiency factor. If the OH and SCP were installed, the IAWWTF's generation would increase by 330% to 67,400,000 scf CH_4/year, which correlates to 7.0 GWh/year of electricity assuming the 35% efficiency factor. It is expected that a greater energy benefit could be realized if that facility utilized the biogas in different forms such as compressed natural gas (CNG) where the conversion efficiency is higher.

7.9.3 Potential to Explore Future Energy Savings

There is potential for further energy savings to the IAWWTF that are outside of the scope of this project but merit future research and study. It is expected that further energy reduction will be realized due to the reduction in WAS pumping in the secondary treatment process and reduction in operation of the Actiflo process at the facility. Additional benefit is also expected to come from the utilization of the SCP technology for the improved trash removal and dewatering from the sludge prior to being fed to the digester.

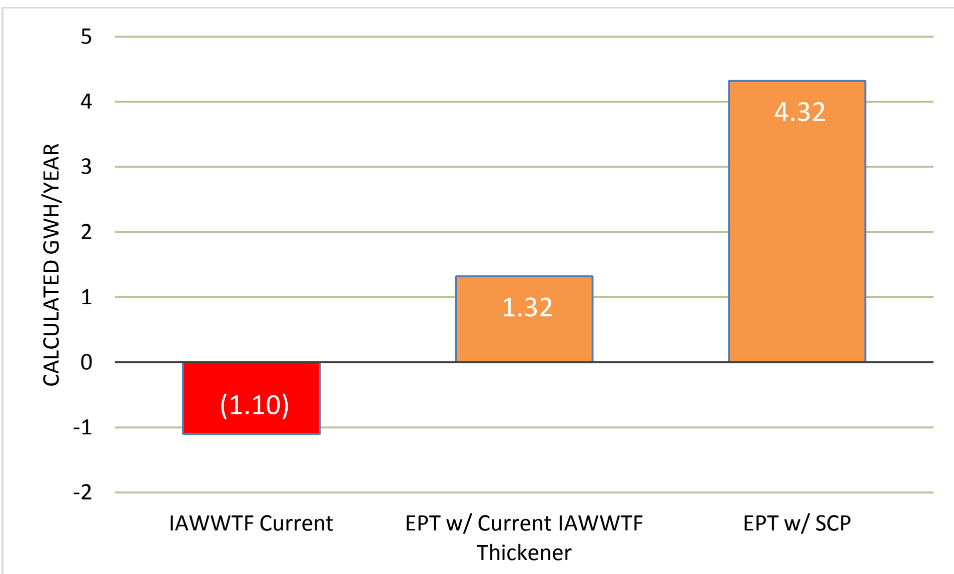
As shown in the Table 14 and Figure 50, the installation of the OH is expected to satisfy the on-site energy demand of the IAWWTF and produce excess biogas for the facility to utilize in another manner, such as conversion to CNG based on calculations using the demonstration data from the OH pilot and pilot digesters. If the OH and SCP solution were installed, the potential for approximately $404,000 worth of excess energy value could be created by the IAWWTF. For the full details of the energy balance calculations, refer to Appendix H.

Table 14. Calculated Plant Energy Balance – Electricity

Net Energy Value calculated using $0.095/kWh.

	IAWWTF Historical Current	Full-scale OH with Current Thickener	Full-scale OH with SCP
Energy Consumption (GWh/year)	3.3	2.7	2.7
Energy Production (GWh/year)	2.2	4.0	7.0
Net Energy (GWh/year)	-1.1	1.3	4.3
Net Energy Value ($/year)	-$104,500	$127,000	$411,000

Figure 50. Calculated Plant Energy Balance



8 Conclusions

The goal of the project was to demonstrate that the majority of wastewater organics could be removed by the OH technology at the primary treatment stage and that removal of the majority of the organics at this treatment stage should lead to reduced energy requirements for subsequent activated sludge secondary treatment. In addition to achieving these goals, data was collected via pilot OH, SCP, and digesters that suggests that full-scale installation of a combined OH/SCP system could not only allow the IAWWTF to achieve net-zero energy operation, but net-positive energy operation. Specific conclusions drawn from the project are outlined in the remainder of this section.

Quantifying aeration energy savings as a result of enhanced BOD removal. The ClearCove pilot OH unit achieved an average BOD removal of 67%. If the system were installed at full-scale, this could result in a significantly lower organic load to the IAWWTF's activated sludge process. This reduced organic load should result in an expected 52% reduction in aeration energy consumption for BOD removal, the equivalent of approximately $56,000/ year.

Measuring increased biogas generation as a result of enhanced primary sludge capture. The OH pilot demonstrated influent VSS capture of 85% while the IAWWTF primary clarifier captured 11% of the influent VSS. The VSS captured within the OH system had a higher methane yield as demonstrated by both the pilot digesters and BMP testing. The installation of the OH at full scale is expected to increase the IAWWTF methane production from primary sludge by 260%, if the existing thickener is used. If the existing thickener is replaced with an SCP further increases the methane generation from primary sludge is anticipated to increase by 520%. This increase would increase the facility's total methane generation by 185% to 320%.

Increasing relative capacity of the digesters as a result of increased sludge biodegradability and improved inorganics removal. Both the pilot digesters and the BMP testing demonstrated that the OH sludge can be loaded at double the VS loading rate and still achieve a similar methane yield and solids destruction rate as the normal loading rate. This supports the hypothesis that the OH sludge is more biodegradable than the sludge fed in the conventional process and WAS and could thus reduce the SRT for the digester.

Improved sludge processing as a result of higher percent solids and improved ratio of primary to secondary sludge. The OH pilot unit achieved 84% TSS and 85% VSS removal. At full scale, this could result in the majority of the sludge being captured in the primary treatment process, increasing the volume of primary sludge and, in the case of the SCP, eliminating the volume of WAS going to anaerobic digestion.

The SCP removes all solids greater than 1/16-inch and compresses them to form a high solids sludge cake for disposal off site. Compressing and grinding of the primary solids is known to increase COD; small particle sizes increase the surface area resulting in faster biodegradation; and the removal of large solids reduces fouling and increases the active volume of the digester. The SCP provides a low odor efficient environment to clean the primary sludge because it is sealed; operates under low pressure; and discharges to an enclosed (zero access) thickener that can be fitted with intake and exhaust ports to move air to an odor control unit without removing conditioned air from the room.

Full-scale OH installation plant chemical usage/costs compared to current chemical usage/costs. The IAWWTF currently doses 50-100 GPD of ferrous chloride at the front of the plant and 400-500 GPD of ferric chloride in its Actiflo process for phosphorus polishing, With the installation of a full-scale OH, this chemical usage would not be increased but, instead, the 500 GPD of ferric chloride would be dosed through the OH at the front of the facility. This would potentially offset the need for the additional 50-100 GPD of ferrous sulfate that is currently being added there now. The chemical cost to the facility would remain the same, with the potential for being less in the event of the elimination of the ferrous chloride usage.

9 Findings that Impact Plant Design

A major concern with installing innovative technologies is lack of data showing stable operations and performance. The pilot OH and SCP provided consistent stable operations for the entire six-month demonstration period. The pilot SCP worked as expected with no mechanical or operational issues.

As data were being generated and field observations conducted, discussions on incorporating the technology at full-scale at IAWWTF began. Conversations with the IAWWTF staff and engineer on how best to incorporate the OH and SCP, a review of the existing plant drawings, and the development of several mass balances, uncovered numerous potential benefits associated with a full-scale OH/SCP upgrade, some of which include:

- Sizing the OH hydraulically for maximum average diurnal flows captures the organic content of an average daily flow. The higher flows associated with inflow and infiltration do not significantly increase the organic load to the plant, only the hydraulic load. The existing primary clarifiers would remain in place and would treat flows exceeding the OH capacity. In this scenario, the sludge captured by the primary clarifiers would also be sent to the SCP.
- The sludge cleaning and thickening that should be provided by a full-scale SCP installation would allow for the primary sludge to be delivered directly from the SCP to the primary digester, thus bypassing the existing sludge thickeners. The Actiflo sludge would be sent directly to dewatering after thickening, because there is little value to sending the Actiflo sludge to the existing primary digester. There is little biogas generation capability in this waste stream and it serves to reduce the hydraulic retention time in the primary digester. Finally, the WAS could also be sent directly to dewatering instead of thickening and then to the primary digester as is currently the case. Moving both the Actiflo and the WAS to dewatering increases the HRT of the primary digester, enabling the receipt of more OH primary sludge and trucked waste from the new solid waste receiving facility.

10 References

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Appendix A. OH Optimization

A-1. COD, Turbidity, UVAS Removal

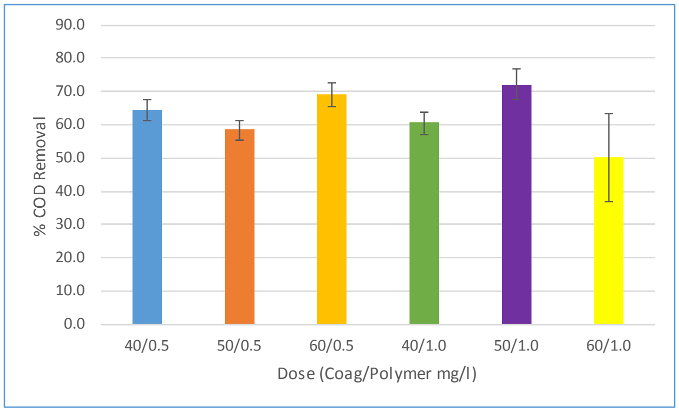
Date	Inf COD	Eff COD	COD Removal	Inf UVAS Avg	Eff UVAS Avg	UVAS % Removal	Inf Turb	Eff Turb	Turb Removal
June 5th	770.00	270.00	65%	1474.75	671.09	54%	143.00	91.00	36%
June 5th	633.00	252.00	60%	1434.44	672.59	53%	118.00	93.00	21%
June 5th	741.00	255.00	66%	1410.44	650.55	54%	100.00	81.00	19%
June 6th	765.00	148.00	81%	1843.71	750.98	59%	90.00	51.00	43%
June 6th	612.00	100.00	84%	1630.71	684.01	58%	56.00	39.00	30%
June 6th	665.00	103.00	85%	1590.71	713.43	55%	48.00	38.00	21%
June 6th	193.00	93.00	52%	1521.00	659.05	57%	63.00	33.00	48%
June 6th	506.00	205.00	59%	1128.00	308.11	73%	67.00	22.00	67%
June 6th	704.00	219.00	69%	1658.13	550.54	67%	130.00	49.00	62%
June 6th	934.00	152.00	84%	1696.86	476.32	72%	146.00	56.00	62%
June 6th	198.00	102.00	48%	1530.00	674.82	56%	79.00	35.00	56%
June 9th	60.00	45.00	25%	1518.57	412.00	73%	40.00	20.00	50%
June 9th	103.00	48.00	53%	1561.71	487.67	69%	50.00	40.00	20%
June 9th	115.00	42.00	63%	1540.25	468.68	70%	83.00	27.00	67%
June 10th	547.00	189.00	65%	1648.33	518.33	69%	163.00	54.00	67%
June 10th	493.00	165.00	67%	1715.75	489.82	71%	156.00	52.00	67%
June 10th	422.00	163.00	61%	1645.50	505.78	69%	124.00	57.00	54%
June 11th	260.00	91.00	65%	1248.00	438.73	65%	71.00	49.00	31%
June 11th	256.00	85.00	67%	1705.00	481.84	72%	120.00	35.00	71%
June 11th	244.00	144.00	41%	1245.33	428.68	66%	114.00	48.00	58%
June 11th	225.00	92.00	59%				115.00	52.00	55%
June 12th	369.00		100%	1656.44	539.10	67%	86.00	79.00	8%
June 12th	515.00	203.00	61%	1588.25	484.45	69%	101.00	57.00	44%
June 12th	281.00	125.00	56%	1529.33	431.32	72%	50.00	49.00	2%
June 12th	343.00	140.00	59%	1560.67	425.58	73%	100.00	49.00	51%
June 17th	373.00	192.00	49%	1358.60	678.41	50%	171.00	96.00	44%
June 18th	287.00	128.00	55%	1352.25	506.04	63%	154.00	69.00	55%
June 18th	305.00	148.00	51%	1414.14	612.44	57%	151.00	80.00	47%
June 18th	240.00	106.00	56%	1304.63	510.06	61%	120.00	55.00	54%
June 19th	297.00	105.00	65%	1469.11	544.89	63%	176.00	79.00	55%
June 19th	268.00	100.00	63%	1535.38	475.74	69%	152.00	51.00	66%
June 20th	289.00	110.00	62%	1411.56	410.16	71%	130.00	51.00	61%
June 20th	291.00	172.00	41%	1451.13	615.82	58%	139.00	81.00	42%
June 20th	332.00	127.00	62%	1563.75	506.01	68%	159.00	50.00	69%
June 27th	418.00	109.00	74%				158.00	58.00	63%
June 27th	297.00	99.00	67%				151.00	49.00	68%
June 28th	331.00	124.00	63%				154.00	62.00	60%
June 30th	420.00	194.00	54%				175.00	67.00	62%
July 1st	375.00	161.00	57%				191.00	82.00	57%
July 1st	893.00	126.00	86%				1100.00	109.00	90%
July 2nd	372.00	132.00	65%				191.00	84.00	56%
July 2nd	366.00	146.00	60%				193.00	80.00	59%
July 3rd	288.00	161.00	44%				184.00	127.00	31%
July 3rd	277.00	149.00	46%				188.00	151.00	20%
No Date	262.00	96.00	63%	2458.67	471.73	81%	143.00	58.00	59%
No Date	269.00	115.00	57%	2413.33	475.06	80%	143.00	57.00	60%
No Date	288.00	113.00	61%	2255.75	471.81	79%	126.00	53.00	58%
No Date	430.00	122.00	72%	1749.50	656.02	63%	280.00	91.00	68%
No Date	291.00	66.00	77%	1415.33	572.02	60%	159.00	60.00	62%
No Date	299.00	101.00	66%	1494.33	514.14	66%	167.00	56.00	66%
No Date	289.00	78.00	73%	1568.75	510.42	67%	130.00	59.00	55%
No Date	286.00	106.00	63%	1747.17	471.98	73%	149.00		
No Date		122.00		1466.00	451.18	69%			

A-2. Dosage Optimization

Data Summary

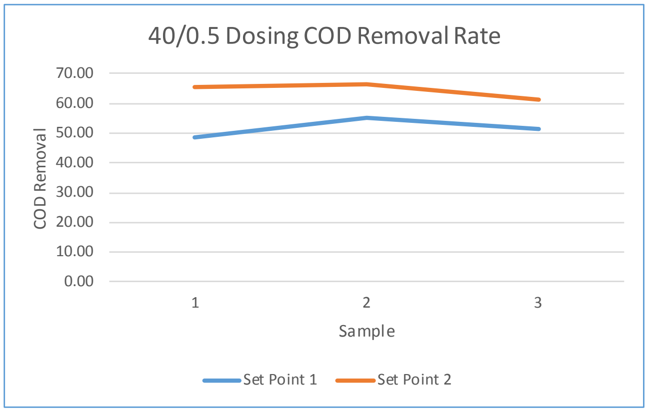
Set Point	Dose (Coag/Polymer mg/l)	Average % Removal
1	40/0.5	51.8
1	50/0.5	56.2
1	60/0.5	61.1
1	40/1.0	40.9
1	50/1.0	56.8
1	60/1.0	56.7

Set Point	Dose (Coag/Polymer mg/l)	Average % Removal
2	40/0.5	64.5
2	50/0.5	58.4
2	60/0.5	69.1
2	40/1.0	60.5
2	50/1.0	72.2
2	60/1.0	50.0



40/0.5

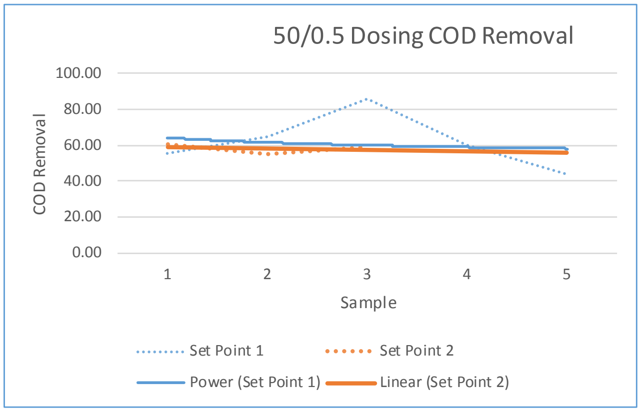
Sample	Set Point 1	Set Point 2
1	48.53	65.45
2	55.40	66.53
3	51.48	61.37
	51.80	64.45



50/0.5

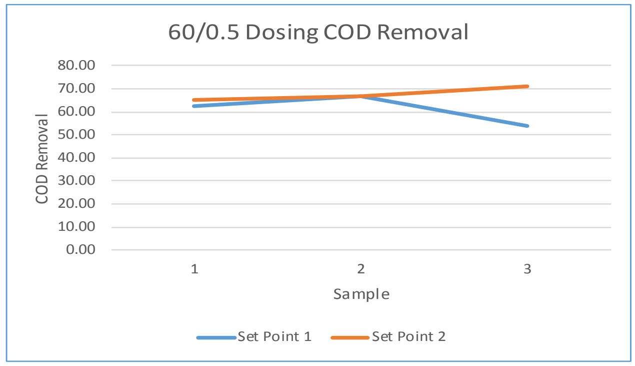
Sample	Set Point 1	Set Point 2
1	55.83	60.58
2	64.65	55.52
3	85.89	59.18
4	60.11	
5	44.10	
	56.17	58.43

High due to tank cleaning



60/0.5

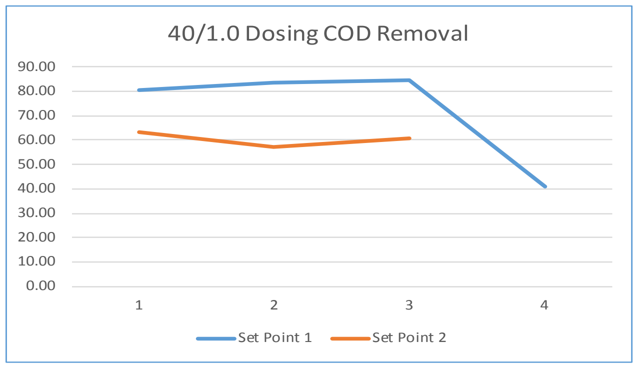
Sample	Set Point 1	Set Point 2
1	62.69	65.00
2	66.67	66.80
3	53.81	71.34
	61.05	67.71



40/1.0

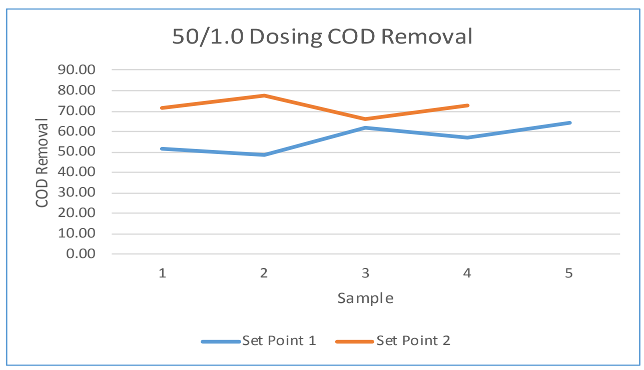
Sample	Set Point 1	Set Point 2
1	80.65	63.36
2	83.66	57.25
3	84.51	60.76
4	40.89	
	72.43	60.46

High due to tank cleaning



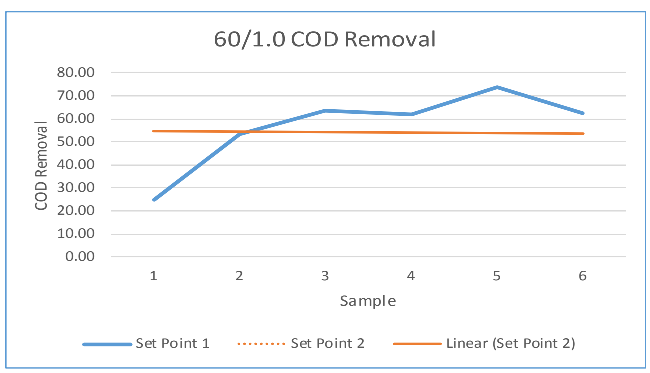
50/1.0

Sample	Set Point 1	Set Point 2
1	51.81	71.63
2	48.48	77.32
3	61.94	66.22
4	57.07	73.01
5	64.52	
	56.76	72.04



60/1.0

Sample	Set Point 1	Set Point 2
1	25.00	62.94
2	53.40	
3	63.48	40.98
4	61.75	
5	73.92	
6	62.54	59.11
	56.68	50.05



Appendix B. OH Operation and Performance

B-1. 80 mg/L Ferric, 0.25 mg/L Anionic Polymer Detail

80 MGL Ferric / .25 MGL Poly												
Date*	**Sampler**	**Type**	**Inf BOD**	**EPT Eff BOD**	**EPT BOD Rem**	**Inf SBOD**	**EPT Eff SBOD**	**EPT SBOD Rem**	**Inf TSS**	**EPT Eff TSS**	**EPT TSS Rem**
7/29/2014	AW	Comp	276	67	76%	24	14	42%	360	45	88%
7/30/2014	AW	Comp	161	63	61%	45	33	27%	176	40	77%
8/1/2014	AW	Comp	159	48	70%	37	36	3%	236	22	91%
8/5/2014	AW	Comp	126	49	61%	29	25	14%	234	30	87%
8/6/2014	AW	Comp	105	32	70%	23	12	48%	147	33	78%
8/7/2014	AW	Comp	150	31	79%	19	15	21%	280	26	91%
9/2/2014	CW	Comp	148	62.0	58%	17	15	12%	214	46	79%
9/3/2014	SM	Comp	191	73	62%	34	31	9%	293	43	85%
9/4/2014	AW	Comp	174	70	60%	40	30	25%	213	40	81%
9/5/2014	AW	Comp	162	43	73%	51	38	25%	260	38	85%
9/8/2014	SM	Comp	179	51	72%	26	16	38%	240	42	83%
9/9/2014	CW	Comp	184	74	60%	47	36	23%	187	25	87%
9/10/2014	CW	Comp	196	62	68%	27	13	52%	260	41	84%
9/11/2014	CW	Comp	136	38	72%	62	53	15%	196	33	83%
9/12/2014	CW	Comp	211	66	69%	42	31	26%	256	39	85%
Min			**105**	**31**	**58%**	**17**	**12**	**3%**	**147**	**22**	**77%**
Max			**276**	**74**	**79%**	**62**	**53**	**52%**	**360**	**46**	**91%**
Avg			**171**	**55**	**67%**	**35**	**27**	**25%**	**237**	**36**	**84%**

80 MGL Ferric / .25 MGL Poly												
Date*	**Inf VSS**	**EPT Eff VSS**	**EPT VSS Rem**	**Inf COD**	**EPT Eff COD**	**EPT COD Rem**	**Inf Phos**	**EPT Eff Phos**	**Phos Removal**	**Inf TKN**	**EPT Eff TKN**	**TKN Removal**
7/29/2014	393	43	89%	760	138	82%	6.49	1.22	81%	35.90	17.90	50%
7/30/2014	148	35	76%	440	270	39%	3.75	0.78	79%	23.60	18.40	22%
8/1/2014	218	20	91%	180	63	65%	3.09	0.69	78%	22.90	17.80	22%
8/5/2014	164	18	89%	240	110	54%	2.27	0.75	67%	17.50	13.10	25%
8/6/2014	130	33	75%	220	100	55%	2.44	0.49	80%	15.80	11.00	30%
8/7/2014	240	22	91%	260	85	67%	3.60	0.62	83%	27.20	14.40	47%
9/2/2014	162	36	78%	341	112	67%	3.94	1.33	66%	35.60	23.70	33%
9/3/2014	193	32	83%	390	154	61%	3.22	0.95	83%	28.20	21.50	24%
9/4/2014	147	25	83%	341	112	67%	2.97	0.89	70%	25.20	21.80	13%
9/5/2014	227	29	87%	391	133	66%	3.48	0.98	72%	27.60	22.00	20%
9/8/2014	200	27	87%	428	120	72%	3.86	0.95	75%	29.10	21.80	25%
9/9/2014	136	18	87%	333	134	60%	3.94	1.15	71%	32.00	25.20	21%
9/10/2014	207	30	86%	350	184	47%	4.00	1.19	70%	34.40	27.60	20%
9/11/2014	153	21	86%	391	134	66%	3.37	2.18	35%	39.00	34.10	13%
9/12/2014	200	27	87%	350	154	56%	3.75	0.96	74%	34.10	28.00	18%
Min	**130**	**18**	**75%**	**180**	**63**	**39%**	**2.3**	**0.5**	**35%**	**15.8**	**11.0**	**13%**
Max	**393**	**43**	**91%**	**760**	**270**	**82%**	**6.5**	**2.2**	**83%**	**39.0**	**34.1**	**50%**
Avg	**195**	**28**	**85%**	**361**	**134**	**62%**	**3.6**	**1.0**	**72%**	**28.5**	**21.2**	**26%**

B-2. 50 mg/L Ferric , 1.0 mg/L Anionic Polymer Detail

50 MGL Ferric /1 MGL Poly												
Date*	Sampler	Type	Inf BOD	EPT Eff BOD	EPT BOD Rem	Inf SBOD	EPT Eff SBOD	EPT SBOD Rem	Inf TSS	EPT Eff TSS	EPT TSS Rem
8/12/2014	AW	Comp	141	52	63%	35	16	54%	244	26	89%
8/15/2014	AW	Comp	117	51	56%	28	18	36%	140	37	74%
8/18/2014	SM	Comp	106	33	69%	12	8	32%	152	36	76%
8/19/2014	AW	Comp	201	60	70%	27	21	22%	192	38	80%
8/20/2014	SM	Comp	210	96	54%	45	38	16%	264	57	78%
8/21/2014	AW	Comp	138	47	66%	19	15	21%	204	34	83%
8/26/2014	BH	Comp	166	76	54%	60	55	8%	200	53	74%
8/27/2014	SM	Comp	165	78	53%	51	35	31%	176	56	68%
8/29/2014	SM	Comp	189	94	50%	49	48	2%	198	53	73%
Min			**106**	**33**	**50%**	**12**	**8**	**2%**	**140**	**26**	**68%**
Max			**210**	**96**	**70%**	**60**	**55**	**54%**	**264**	**57**	**89%**
Avg			**159**	**65**	**60%**	**36**	**28**	**25%**	**197**	**43**	**77%**

50 MGL Ferric /1 MGL Poly												
Date*	Inf VSS	EPT Eff VSS	EPT VSS Rem	Inf COD	EPT Eff COD	EPT COD Rem	Inf Phos	EPT Eff Phos	Phos Removal	Inf TKN	EPT Eff TKN	EPT TKN Removal
8/12/2014	140	26	81%	280	110	61%	2.91	0.98	66%	22.20	14.20	36%
8/15/2014	120	33	73%	260	100	62%	2.65	1.01	62%	20.30	15.60	23%
8/18/2014	116	27	77%	156	78	50%	2.85	0.79	72%	20.80	15.60	25%
8/19/2014	172	29	83%	272	118	57%	3.75	1.04	72%	28.80	18.60	35%
8/20/2014	228	47	79%	352	156	56%	4.96	1.28	74%	29.30	19.60	33%
8/21/2014	168	25	85%	216	100	54%	2.99	0.78	74%	20.10	14.90	26%
8/26/2014	172	43	75%	310	190	39%	3.48	1.23	65%	26.40	23.50	11%
8/27/2014	170	48	72%	340	140	59%	3.78	1.38	63%	30.80	25.30	18%
8/29/2014	170	42	75%	439	150	66%	3.79	1.66	56%	38.00	31.40	17%
Min	**116**	**25**	**72%**	**156**	**78**	**39%**	**2.65**	**0.78**	**56%**	**20.10**	**14.20**	**11%**
Max	**228**	**48**	**85%**	**439**	**190**	**66%**	**4.96**	**1.66**	**74%**	**38.00**	**31.40**	**36%**
Avg	**162**	**36**	**78%**	**292**	**127**	**56%**	**3.46**	**1.13**	**67%**	**26.30**	**19.86**	**25%**

B-3. Conventional Primary Clarifier Removal

Publication	WEF Clarifier Design	IWA Water Research	IWA Water Science and Technology	Average Removal No Chemical
Author(s)	Wilson et al.	Puig et al.	Gori et al.	
CEPT	No	No	Ferric Chloride	
BOD	30%		41%	30%
SBOD				
TSS	50%	65%	66%	58%
VSS			67%	
COD	30%		48%	30%
Phos				
TKN				

Appendix C. SCP Operation and Performance

C-1. COD mg/L by Sludge Type Detail

Date	Pre - SCP COD (mg/L)	Post -SCP COD (mg/L)	Decant COD (mg/L)
8/15/14	9823	23511	2051.5
8/18/14	4587	16632	2654
8/20/14	12126	21785	1816
8/22/14	9592	17536	1728
8/27/14	10483	20119	1698
9/3/14	14740	24294	2182
9/4/14	7337	16461	1812
9/8/14	12837	25689	1822
9/10/14	17193	26588	n/a
9/11/14	14630	20553	2738

C-2. % Total Solids of Pre-SCP Sludge and Post-SCP Sludge and Decant Fractions Detail

Date	Pre-SCP % TS	Post-SCP % TS	Decant % TS
8/15/14	0.67	0.69	0.22
8/18/14	0.32	1.22	0.46
8/20/14	0.94	1.49	0.19
8/22/14	0.71	1.46	0.25
8/25/14	0.71	1.23	0.15
8/27/14	0.77	1.35	0.13
9/3/14	1.02	1.42	0.21
9/8/14	0.89	1.62	0.15
9/11/14	1.04	1.35	0.37

C-3. %VS of Pre-SCP Sludge & Post-SCP Sludge and Decant Fractions Details

Date	Pre-SCP % VS	Post-SCP % VS	Decant % VS
8/15/14	81.3	81.5	80.6
8/18/14	68.0	77.7	78.5
8/20/14	80.2	80.4	65.6
8/22/14	73.5	78.1	69.1
8/25/14	78.0	80.1	51.0
8/27/14	87.8	80.5	79.8
9/3/14	80.8	80.3	71.2
9/8/14	76.8	79.0	41.3
9/11/14	78.8	79.8	73.7

Appendix D. BMP Operation and Performance

D-1. BMP Data Detail

Start Date	Stop Date	Source	Detention Time (days)	VS Load (g)	Total Methane (Nml)	Applied Yield (scf methane/ lb VS applied)	Average Applied Yield	Compared to IPS
6/24/2014	7/1/2014	IAWWTF Thickened *	6.8	1.50	345	3.7	3.2	75%
7/1/2014	7/8/2014	IAWWTF Thickened *	6.8	1.36	260	3.1		
7/8/2014	7/24/2014	IAWWTF Thickened	15.0	1.88	352	3.0		
7/25/2014	8/11/2014	IAWWTF Thickened	16.9	1.72	350	3.3		
8/15/2014	9/2/2014	IAWWTF Thickened	18.6	3.24	2,652	13.1		
9/3/2014	9/15/2014	IAWWTF Thickened *	11.0	1.43	281	3.1		
9/17/2014	10/13/2014	IAWWTF Thickened	25.8	1.49	300	3.2		
6/24/2014	7/1/2014	IAWWTF Primary *	6.8	1.55	424	4.4	4.3	100%
7/1/2014	7/8/2014	IAWWTF Primary *	6.8	1.41	430	4.9		
7/8/2014	7/24/2014	IAWWTF Primary	15.0	1.77	481	4.4		
7/25/2014	8/11/2014	IAWWTF Primary	16.9	1.70	477	4.5		
8/15/2014	9/2/2014	IAWWTF Primary	18.6	2.27	851	6.0		
9/3/2014	9/15/2014	IAWWTF Primary *	11.0	1.52	317	3.3		
6/24/2014	7/1/2014	CCS Post-SCP *	6.8	1.17	368	5.0	5.7	132%
7/1/2014	7/8/2014	CCS Post-SCP *	6.8	1.52	631	6.7		
7/8/2014	7/24/2014	CCS Post-SCP	15.0	1.92	611	5.1		
7/25/2014	8/11/2014	CCS Post-SCP	16.9	1.78	630	5.7		
8/15/2014	9/2/2014	CCS Post-SCP	18.6	2.82	1,208	6.9		
9/3/2014	9/15/2014	CCS Post-SCP *	11.0	1.24	449	5.8		
9/17/2014	10/13/2014	CCS Post-SCP *	25.8	1.24	446	5.8		
7/1/2014	7/8/2014	CCS Post-SCP 2X *	6.8	3.06	1,296	6.8	5.6	131%
7/8/2014	7/24/2014	CCS Post-SCP 2X	15.0	3.84	1,340	5.6		
7/25/2014	8/11/2014	CCS Post-SCP 2X	16.9	3.56	1,287	5.8		
8/15/2014	9/2/2014	CCS Post-SCP 2X	18.6	5.63	2,233	6.4		
9/3/2014	9/15/2014	CCS Post-SCP 2X *	11.0	2.48	674	4.4		
9/17/2014	10/13/2014	CCS Post-SCP 2X *	25.8	2.48	870	5.6		
7/8/2014	7/24/2014	Inoculum Only	15.0	3.68	85	0.37	0.7	
7/25/2014	8/11/2014	Inoculum Only	16.9	3.72	205	0.88		
8/15/2014	9/2/2014	Inoculum Only	18.6	2.52	283	1.80		
9/17/2014	10/13/2014	Inoculum Only	25.8	3.28	179	0.87		
9/3/2014	9/15/2014	Thickened Inoculum	11.0	2.84	47	0.27	0.27	
9/3/2014	9/15/2014	Primary Inoculum	11.0	3.00	293	1.6	1.6	
9/3/2014	9/15/2014	Post-SCP Inoculum	11.0	2.40	176	1.2	0.8	
9/17/2014	10/13/2014	Post-SCP Inoculum	25.8	2.40	73	0.5		
9/17/2014	10/13/2014	Post-SCP 2X Inoculum	25.8	1.80	559	5.0	5.0	

* assumes 145 Nml methane from 400 ml inoculum
Average Applied Yield does not include values in red

Appendix E. Pilot Digester Operation and Performance

Pilot Digester #1 – Ithaca Thickened Sludge Daily Operations Detail

	Pilot Digester #1 - Ithaca Thickened Sludge																
Date	Feed Flow	Feed pH	Feed TS	TS Load	Feed VS	VS Load	MD Volume	Digester Temperature	Digester pH	Digester VS Load	Digester TS	Digester VS	VS destroyed	BIOGAS FLOW	Methane	Applied Production (CH4/VS fed)	Destroyed Production (CH4/VS rem)
	L/day	s.u.	%	lb/day	%	lb/day	gal	deg F	s.u.	lb/kcf/d	%	%	lb/day	sL/day	%	scfd/lb	scfd/lb
													31%				
7/14/2014	26		4.6	2.68	61.0	1.64	100	95.8	7.6	122	0.7	57.3	1.40	236		3.6	4.2
7/15/2014	26		2.6	1.52	65.5	0.99	100	95.6	7.5	74	1.6	58.8	0.44	205		5.2	11.5
7/16/2014	26		1.8	1.05	67.1	0.70	100	95.5	7.5	53	0.7	58.2	0.47	149		5.3	7.9
7/17/2014	26			1.26		0.79	100	95.6		59				203		6.4	
7/18/2014	26			1.26		0.79	100	95.8		59				153	80	4.8	
7/19/2014	26			1.26		0.79	100	95.7		59				48		1.5	
7/20/2014	26			1.26		0.79	100	95.6		59				55		1.7	
7/21/2014	26		1.1	0.64	66.7	0.43	100	95.5	7.8	32	0.4	56.8	0.30	74	80	4.3	6.3
7/22/2014	26			1.26		0.79	100	95.9	7.7	59				151		4.7	
7/23/2014	42			2.03		1.27	100	95.7	7.8	95	1.5	59.1	0.45	144	80	2.8	8.1
7/24/2014	42		1.2	1.12	62.7	0.70	100	95.4	7.3	53				125		4.4	
7/25/2014	42			2.03		1.27	100	94.8		95				212		4.2	
7/26/2014	42			2.03		1.27	100	94.1		95				234		4.6	
7/27/2014	42			2.03		1.27	100	94.3		95				222		4.4	
7/28/2014	42		0.87	0.81	60.3	0.49	100	93.1	7.3	37	0.6	61.6	0.13	199		10.1	38.9
7/29/2014	42			2.03		1.27	100	93.2		95				231		4.5	
7/30/2014	42		2.1	1.96	68.9	1.35	100	95.8	7.4	101	1.4			161		3.0	
7/31/2014	42		4.5	4.21	62.1	2.61	100	96.0	7.3	195	2.3			224		2.1	
8/1/2014	42			2.03		1.27	100	96.1	7.1	95				315		6.2	
8/2/2014	42			2.03		1.27	100	96.1		95				256		5.0	
8/3/2014	42			2.03		1.27	100	95.7		95				197		3.9	
8/4/2014	42		2.8	2.62	59.0	1.54	100	95.8	7.2	115	1.2	58.7	0.89	87	70	1.4	2.4
8/5/2014	42		1.9	1.78	67.1	1.19	100	95.7		89				140	74	3.1	
8/6/2014	21			1.00	60.2	0.60	100	95.8	7.3	45	1.5	60.4	0.19	204	76	9.1	27.5
8/7/2014	21	6.4	1.5	0.69	63.6	0.44	100	95.6	7.2	33	1.5	59.3	0.03	179	75	10.8	149.9
8/8/2014	21	6.2		1.00		0.63	100	95.8	7.1	47				163	65	5.9	
8/9/2014	21	7.1		1.00		0.63	100	96.0	7.4	47				193		7.6	
8/10/2014	21			1.00		0.63	100	95.8		47				140		5.6	
8/11/2014	21	6.9		1.00		0.63	100	95.5	7.2	47				186	68	7.1	
8/12/2014	21		2.9	1.34	61.3	0.82	100	95.7		61	0.7	54.1	0.64	184	72	5.7	7.2
8/13/2014	21	6.8	3.5	1.62	64.4	1.04	100	96.0	7.7	78	1.3	54.0	0.72	161	70	3.8	5.6
8/14/2014	31	7.0	1.3	0.90	63.2	0.57	100	95.6	7.9	42	2.2	57.7	-0.31	125	70	5.5	
8/15/2014	31	6.8	1.9	1.31	63.1	0.83	100	95.5	7.4	62	1.6	58.7	0.18	248	70	7.4	34.6
8/16/2014	31	7.0		1.50		0.94	100	95.0	7.4	70				247	70	6.5	
8/17/2014	31	7.1		1.50		0.94	100	95.2	6.9	70				342	70	9.0	
8/18/2014	31	6.8	3.3	2.28	61.4	1.40	100	95.0	7.4	105	1.5	57.4	0.80	372	72	6.8	11.5
8/19/2014	31	7.0	3.0	2.07	62.3	1.29	100	94.8	7.5	97	2.0	56.6	0.51	463	75	9.5	22.7
8/20/2014	31	6.9	3.0	2.07	62.9	1.30	100	96.0	7.3	97	1.9	56.7	0.56	392	70	7.4	17.5
8/21/2014	31		3.0	2.07	62.3	1.29	100	96.0	7.1	97	0.5	51.6	1.11	407	74	8.2	9.2
8/22/2014	31	6.9	3.2	2.21	63.1	1.39	100	95.7	7.2	104	1.3	59.9	0.86	393	74	7.4	11.4
8/23/2014	31			1.50		0.94	100	95.7	7.3	70				294	70	7.7	
8/24/2014	31			1.50		0.94	100	95.6	7.4	70				238	70	6.3	
8/25/2014	31		2.1	1.45	62.8	0.91	100	95.9	7.3	68	2.0	58.3	0.11	247	70	6.7	58.3
8/26/2014	22	6.6	1.2	0.57	67.2	0.38	100	97.3	7.4	29	2.8	58.0	-0.39	176	70	11.4	
8/27/2014	22		0.7	0.31	59.6	0.18	100	97.9	7.2	14				141	70	18.9	
8/28/2014	22	6.9	0.9	0.43	68.5	0.29	100	97.5	7.2	22	1.5	58.7	-0.13	120	70	10.2	
8/29/2014	22			1.03		0.65	100	97.9	7.3	48				111	70	4.2	
8/30/2014	22			1.03		0.65	100	97.3	7.3	48				99	70	3.8	
8/31/2014	22			1.03		0.65	100	97.8	7.3	48				71	70	2.7	
9/1/2014	22			1.03		0.65	100	97.9	7.3	48				40	70	1.5	
9/2/2014	29	7.2	1.3	0.84	60.3	0.50	100	97.8	7.3	38	1.2	57.7	0.06	22	70	1.1	9.1
9/3/2014	15		3.1	1.03	60.4	0.62	100	97.3		46	1.4	59.2	0.35	46	68	1.8	3.2
9/4/2014	15	7.1		0.72		0.45	100	96.9	7.1	34				65	72	3.6	
9/5/2014	19	6.9		0.91		0.58	100	97.9	7.2	43				73	66	3.0	
9/6/2014	9	7.0		0.44		0.27	100	97.2	7.2	20				44	68	3.9	
9/7/2014	9			0.41		0.26	100	97.0	7.3	19				55	70	5.2	
9/8/2014	9			0.44		0.27	100	96.8	7.2	20	1.4	57.8	0.11	56	70	5.1	12.5
9/9/2014	17	7.1	1.4	0.52	61.6	0.32	100	95.6	7.2	24	0.7	57.4	0.18	59	70	4.6	8.3
9/10/2014	12			0.57		0.36	100	95.4	7.1	27				73	74	5.4	
9/11/2014	28	6.9	0.8	0.51	61.8	0.32	100	96.5	7.1	24	1.1	61.0	-0.10	51	70	3.9	
9/12/2014	27		0.6	0.34	61.5	0.21	100	96.5	7.1	16	1.1	61.7	-0.19	31	70	3.7	
9/13/2014	27			1.31		0.82	100	94.5	7.1	61				47	70	1.4	
9/14/2014	26			1.22		0.77	100	93.2	7.2	57				59	72	2.0	
9/15/2014								91.0									
	7/14-9/14																
Average	28	SRT	2.1	1.32	63	0.84	100	95.8		62	1.4	58	0.34	169	71	5.04	12.22
Sum	1,769	13.5											41%			3.03	31.83
Vol	379															18.92	149.90
# Rxn	4.7															4.80	10.31
# data pts	63															1.06	2.45
														Methane sL/d	119	63	22

Pilot Digester #2 – Primary Sludge Daily Operations Detail

	Pilot Digester #2A - Ithaca Primary Sludge																
	Feed Flow	Feed pH	Feed TS	TS Load	Feed VS	VS Load	MD Volume	Digester Temperature	Digester pH	Digester VS Load	Digester TS	Digester VS	VS destroyed	BIOGAS FLOW	Methane	Applied Production (CH4/VS fed)	Destroyed Production (CH4/VS rem)
Date	L/day	s.u.	%	lb/day	%	lb/day	gal	deg F	s.u.	lb/kcf/d	%	%	lb/day	sL/day	%	scfd/lb	scfd/lb
4/11/2014	138						400	96.6						111			
4/12/2014	124						400	97.1						330			
4/13/2014	124						400	96.7						380			
4/14/2014	124						400	96.7						165			
4/15/2014	124	6.5	2.0	5.46	84.6	4.62	400	97.1	7.2					209			
4/16/2014	124		1.4	3.82	81.6	3.12	400	97.0		58				324			
4/17/2014	124						400	97.6						509			
4/18/2014	124		0.5	1.23			400	97.2						304			
4/19/2014	124						400	97.4						87			
4/20/2014	124						400	97.7						78			
4/21/2014	114						400	97.1						371			
4/22/2014	114		1.4	3.40	82.4	2.80	400	97.0		52				699			
4/23/2014	114						400	97.0						756			
4/24/2014	114		1.3	3.27	84.1	2.75	400	97.1		51	4.1	58.9	-3.33	216			
4/25/2014	114		2.0	5.03	83.9	4.22	400	97.1		79				277			
4/26/2014	114						400	96.9						102			
4/27/2014	114						400	97.0						69			
4/28/2014	114		2.2	5.54	75.2	4.16	400	97.3		78				65			
4/29/2014	114		1.7	4.28	78.4	3.35	400	97.0		63				510	65	3.2	
4/30/2014	114		2.1	5.28	74.2	3.92	400	97.2		73				435	65	2.4	
5/1/2014	114		1.8	4.53	79.1	3.58	400	97.2		67				523	65	3.1	
5/2/2014	114			5.28		3.62	400	97.1		68				466	65	2.7	
5/3/2014	72			3.33		2.28	400	97.1		43				554	65	5.2	
5/4/2014	72			3.33		2.28	400	96.6		43				304	65	2.8	
5/5/2014	72		1.9	3.01	54.2	1.63	400	96.9		31	2.7	60.8	-0.97	255	65	3.3	
5/6/2014	72		1.8	2.85	58.5	1.67	400	97.2		31	2.1	60.2	-0.33	481	65	6.1	
5/7/2014	72		1.6	2.54	60.6	1.54	400	97.0		29	2.0	59.1	-0.34	448	65	6.2	
5/8/2014	72		1.6	2.54	62.1	1.58	400	96.6		29	3.9	57.9	-2.01	217	65	2.9	
5/9/2014	72			3.33		2.28	400	94.9		43				313	65	2.9	
5/10/2014	72			3.33		2.28	400	94.8		43				256	65	2.4	
5/11/2014	72			3.33		2.28	400	97.3		43				268	65	2.5	
5/12/2014	72		1.9	3.01	55.8	1.68	400	93.0		31	3.6	58.9	-1.68	292	65	3.7	
5/13/2014	72			3.33		2.28	400	97.9		43				639	65	5.9	
5/14/2014	72		2.0	3.17	75.4	2.39	400	106.1		45	1.1	68.9	1.19	524	65	4.6	9.3
5/15/2014	72		2.7	4.28	68.2	2.92	400	96.9		55	2.7	63.4	0.21	610	65	4.4	63.0
5/16/2014	72		2.5	3.96	68.7	2.72	400	96.8		51				674	65	5.3	
5/17/2014	72			3.33		2.28	400	92.3		43				640	65	6.0	
5/18/2014	72			3.33		2.28	400	89.9		43				598	65	5.6	
5/19/2014	72			3.33		2.28	400	92.2		43				446	65	4.1	
5/20/2014	72			3.33		2.28	400	106.0		43				690	65	6.4	
5/21/2014	72			3.33		2.28	400	98.8		43				603	65	5.6	
5/22/2014	72			3.33		2.28	400	94.9		43				837	65	7.8	
5/23/2014	72			3.33		2.28	400	95.3		43				1,101	65	10.2	
5/24/2014	72			3.33		2.28	400	94.9		43				825	65	7.7	
5/25/2014	72			3.33		2.28	400	94.9		43				808	65	7.5	
5/26/2014	72			3.33		2.28	400	92.2		43				432	65	4.0	
5/27/2014	72			3.33		2.28	400	91.6		43				346	65	3.2	
5/28/2014	72			3.33		2.28	400	94.3		43				314	65	2.9	
5/29/2014	72			3.33		2.28	400	95.4		43				428	65	4.0	
5/30/2014	72			3.33		2.28	400	95.6		43				598	65	5.6	
5/31/2014	72			3.33		2.28	400	93.2		43				647	65	6.0	
6/1/2014	72			3.33		2.28	400	90.5		43				713	65	6.6	
6/2/2014	72		3.7	5.87	66.9	3.93	400	89.9		73	2.3	66.3	1.51	303	65	1.6	4.3
6/3/2014	72			3.33		2.28	400	90.4		43				250	65	2.3	
6/4/2014	36			1.67		1.14	200	90.5		43				342	65	6.4	
6/5/2014	36			1.67		1.14	200	90.2		43				230	65	4.3	
6/6/2014	36			1.67		1.14	200	89.8		43				279	65	5.2	
6/7/2014	36			1.67		1.14	200	89.8		43				584	65	10.9	
6/8/2014	36			1.67		1.14	200	89.8		43				646	65	12.0	
6/9/2014	36			1.67		1.14	200	89.8		43				527	65	9.8	
6/10/2014	36			1.67		1.14	200	90.9		43				337	65	6.3	
6/11/2014	36			1.67		1.14	200	93.2		43				117	65	2.2	
6/12/2014	36			1.67		1.14	200	93.7		43				343	65	6.4	
6/13/2014	36			1.67		1.14	200	94.4		43				402	65	7.5	
6/14/2014	36			1.67		1.14	200	93.8		43				416	65	7.7	
6/15/2014	36			1.67		1.14	200	93.8		43				447	65	8.3	
6/16/2014	36			1.67		1.14	200	94.0		43				456	65	8.5	
6/17/2014	36		1.9	1.51	82.8	1.25	200	92.0		47				206	65	3.5	
6/18/2014	4/11-6/17																
Phase 1	80		1.9	3.33	72	2.42	359	95.2		50	2.7	62	-0.53	423	65	4.0	-18.2
													-22%				
														methane	275		

Pilot Digester #2 – Primary Sludge Daily Operations Detail Continued

	Pilot Digester #2A - Ithaca Primary Sludge																
	Feed Flow	Feed pH	Feed TS	TS Load	Feed VS	VS Load	MD Volume	Digester Temperature	Digester pH	Digester VS Load	Digester TS	Digester VS	VS destroyed	BIOGAS FLOW	Methane	Applied Production (CH4/VS fed)	Destroyed Production (CH4/VS rem)
Date	L/day	s.u.	%	lb/day	%	lb/day	gal	deg F	s.u.	lb/kcf/d	%	%	lb/day	sL/day	%	scfd/lb	scfd/lb
7/21/2014	22		1.2	0.57	76.9	0.44	100	97.0	6.0	33	1.1	65.7	0.09	51	75	2.5	11.4
7/22/2014	22			0.95		0.67	100	97.9	6.1	50				133		4.2	
7/23/2014	36		1.1	0.87	74.0	0.65	100	98.2	6.4	48	0.6	66.5	0.31	154	75	5.1	10.6
7/24/2014	36		1.2	0.95	75.3	0.72	100	96.7	6.5	54	1.5	69.4	-0.11	209		6.2	
7/25/2014	36			1.59		1.11	100	96.9		83				211		4.0	
7/26/2014	36			1.59		1.11	100	96.7		83				114		2.2	
7/27/2014	36			1.59		1.11	100	97.6		83				82		1.6	
7/28/2014	36		1.5	1.19	77.8	0.93	100	95.2	6.7	69	1.1	62.7	0.38	46		1.0	2.6
7/29/2014	36			1.59		1.11	100	93.9	6.2	83				105		2.0	
7/30/2014	36		1.4	1.11	79.8	0.89	100	96.6		66	1.0	69.4	0.34	168		4.0	10.6
7/31/2014	36			1.59		1.11	100	96.9	6.1	83	1.5			194		3.7	
8/1/2014	36			1.59		1.11	100	96.8	6.7	83				247		4.7	
8/2/2014	36			1.59		1.11	100	96.9		83				328		6.2	
8/3/2014	36			1.59		1.11	100	96.7		83				280		5.3	
8/4/2014	36			1.59		1.11	100	96.6	6.2	83	1.3	71.7		291	50	4.6	
8/5/2014	36		2.3	1.82	75.7	1.38	100	96.4		103	1.5	72.3	0.52	245	60	3.8	10.0
8/6/2014	21		2.7	1.22	76.2	0.93	100	97.1	6.2	70	1.7	70.8	0.39	239	58	5.3	12.7
8/7/2014	21		1.3	0.59	74.0	0.44	100	96.8	6.1	33	1.9	67.2	-0.14	171	55	7.6	
8/8/2014	21	5.5		0.91		0.64	100	97.0	6.2	48				145	50	4.0	
8/9/2014	21	7.1		0.91		0.64	100	97.0	6.6	48				183		6.1	
8/10/2014	21			0.91		0.64	100	96.8		48				198		6.6	
8/11/2014	21	6.8		0.91		0.64	100	96.4	6.7	48				162	60	5.4	
8/12/2014	21		3.5	1.59	61.0	0.97	100	96.8		72	1.5	65.9	0.52	154	60	3.4	6.3
8/13/2014	21	6.7	2.7	1.22	57.0	0.70	100	97.4	7.6	52	1.8	55.3	0.25	184	58	5.4	15.3
8/14/2014	28	6.8	1.9	1.16	63.6	0.74	100	96.8	7.2	55	0.8	66.2	0.40	169	60	4.9	8.9
8/15/2014	28	6.6	1.6	0.97	62.0	0.60	100	96.0	7.1	45		65.6		170	60	6.0	
8/16/2014	28	6.4					0	92.4						92			
	7/21-8/15																
Average	29	SRT	1.9	1.21	71	0.86	100	96.7		65	1.3	67	0.28	178	60	4.39	13.40
Sum	767	12.8											33%			1.64	3.68
Vol	379															7.60	15.31
# Rxn	2.0															4.66	10.61
# data pts	26															1.04	2.55
														methane	107	26	9
	4/11-6/17, 7/21-8/15																
	66	SRT	1.9	2.74	72	1.97	287	95.6		51	1.9	65	0.18	355	64	4.08	44.45
	6,198	16.5											9%			2.23	15.92
	1,087															12.01	63.0
	5.7															4.97	10.3
	94															1.04	2.6
														methane	227	76	12

Pilot Digester #3 – ClearCove Enhanced Primary Sludge Daily Operations Detail

	Pilot Digester #3 - ClearCove Enhanced Primary Sludge																
	Feed Flow	Feed pH	Feed TS	TS Load	Feed VS	VS Load	MD Volume	Digester Temperature	Digester pH	Digester VS Load	Digester TS	Digester VS	VS destroyed	BIOGAS FLOW	Methane	Applied Production (CH4/VS fed)	Destroyed Production (CH4/VS rem)
Date	L/day	s.u.	%	lb/day	%	lb/day	gal	deg F	s.u.	lb/kcf/d	%	%	lb/day	sL/day	%	scfd/lb	scfd/lb
4/11/2014	115						400	96.7						101	83		
4/12/2014	115						400	97.4	7.3					196			
4/13/2014	115						400	96.8	7.2					324			
4/14/2014	115						400	96.8	7.4					466			
4/15/2014	115	6.1	1.6	4.06			400	97.3	7.1					483	86		
4/16/2014	115		2.1	5.25			400	97.2	7.5					310			
4/17/2014	115						400	97.7	7.4					303	82		
4/18/2014	115						400	97.5						353	81		
4/19/2014	60						400	97.8						467			
4/20/2014	60						400	97.7						445	80		
4/21/2014	60						400	97.2						362	74		
4/22/2014	60		1.1	1.39			400	97.3						232	76		
4/23/2014	60		0.7	0.93			400	97.1						175			
4/24/2014	106		1.0	2.33	77.7	1.81	400	97.4		34	3.7	55.8	-2.99	239			
4/25/2014	106		1.9	4.42	83.6	3.69	400	96.8		69				1,895			
4/26/2014	106						400	97.4						908			
4/27/2014	106						400	97.5						996			
4/28/2014	106		1.6	3.72	84.0	3.13	400	96.7		58	5.0	54.5	-3.21	933		7.5	
4/29/2014	106		1.5	3.49	82.7	2.89	400	97.5		54				792		6.9	
4/30/2014	106		1.0	2.33	84.5	1.97	400	97.8		37	1.3	76.7	-0.35	886	78	11.4	
5/1/2014	106		1.8	4.19	84.1	3.52	400	97.3		66	1.5	73.2	0.97	1,130		8.1	
5/2/2014	106			2.99		2.39	400	97.3		45				1,339	76	14.2	
5/3/2014	71			2.01		1.61	400	97.5		30				876		13.8	
5/4/2014	71			2.01		1.61	400	97.0		30				499		7.9	
5/5/2014	71		1.1	1.72	76.4	1.32	400	97.2		25	2.4	64.2	-1.10	356	70	6.8	
5/6/2014	71		1.2	1.88	77.3	1.45	400	97.2		27	0.9	65.1	0.49	705	70	12.3	35.3
5/7/2014	71		1.0	1.56	70.5	1.10	400	97.0		21	1.8	66.0	-0.76	675	70	15.5	
5/8/2014	71		1.6	2.50	76.6	1.92	400	96.6		36	2.8	64.9	-0.93	414	69	5.5	
5/9/2014	71			2.01		1.61	400	94.3		30				517	70	8.1	
5/10/2014	71			2.01		1.61	400	93.9		30				510	70	8.0	
5/11/2014	71			2.01		1.61	400	97.0		30				584	70	9.2	
5/12/2014	71		2.8	4.38	77.2	3.38	400	96.9		63	1.0	69.6	2.29	711	70	5.3	
5/13/2014	71			3.65		2.83	400	97.2		53				749	70	6.7	
5/14/2014	71		2.1	3.29	80.8	2.66	400	97.2		50	0.7	76.0	1.86	670	70	6.4	
5/15/2014	71		3.0	4.69	74.3	3.49	400	97.2		65	1.9	68.0	1.47	717	70	5.2	
5/16/2014	71		2.3	3.60	76.0	2.74	400	97.2		51				667	70	6.2	
5/17/2014	71			3.65		2.83	400	97.0		53				743	70	6.6	
5/18/2014	71			3.65		2.83	400	97.5		53				915	70	8.2	
5/19/2014	71			3.65		2.83	400	97.1		53				859	70	7.7	
5/20/2014	71			3.65		2.83	400	97.2		53				745	70	6.6	
5/21/2014	71			3.65		2.83	400	94.5		53				788	70	7.0	
5/22/2014	71			3.65		2.83	400	95.5		53				877	70	7.8	
5/23/2014	71			3.65		2.83	400	94.6		53				985	70	8.8	
5/24/2014	71			3.65		2.83	400	94.3		53				1,311	70	11.7	
5/25/2014	71			3.65		2.83	400	94.9		53				991	70	8.8	
5/26/2014	71			3.65		2.83	400	92.1		53				524	70	4.7	
5/27/2014	71			3.65		2.83	400	91.5		53				327	70	2.9	
5/28/2014	71			3.65		2.83	400	93.9		53				270	70	2.4	
5/29/2014	71			3.65		2.83	400	94.7		53				504	70	4.5	
5/30/2014	71			3.65		2.83	400	95.2		53				772	70	6.9	
5/31/2014	71			3.65		2.83	400	95.1		53				870	70	7.8	
6/1/2014	71			3.65		2.83	400	94.9		53				873	70	7.8	
6/2/2014	71		1.3	2.03	80.2	1.63	400	94.9		31	3.5	61.0	-1.71	973	70	15.1	
6/3/2014	71			3.65		2.83	400	95.1		53				1,016	70	9.1	
6/4/2014	36			1.83		1.42	200	94.6		53				1,078	70	19.2	
6/5/2014	36			1.83		1.42	200	94.4		53				736	70	13.1	
6/6/2014	36			1.83		1.42	200	94.7		53				1,006	70	17.9	
6/7/2014	36			1.83		1.42	200	94.6		53				311	70	5.5	
6/8/2014	36			1.83		1.42	200	94.5		53				457	70	8.1	
6/9/2014	36			1.83		1.42	200	94.2		53				705	70	12.6	
6/10/2014	36			1.83		1.42	200	96.1		53				992	70	17.7	
6/11/2014	36			1.83		1.42	200	97.4		53				823	70	14.7	
6/12/2014	36			1.83		1.42	200	97.0		53				730	70	13.0	
6/13/2014	36			1.83		1.42	200	97.2		53				582	70	10.4	
6/14/2014	36			1.83		1.42	200	96.0		53				600	70	10.7	
6/15/2014	36			1.83		1.42	200	96.2		53				669	70	11.9	
6/16/2014	36			1.83		1.42	200	96.9		53				658	70	11.7	
6/17/2014	36		2.5	1.96	76.9	1.50	200	94.1		56				272	70	4.6	
6/18/2014	4/11-6/17																
Phase 1	73		1.7	2.65	79	2.09	359	96.2		44	2.2	66	-0.25	676	72	8.2	-68.2
														methane	484		

Pilot Digester #3 – ClearCove Enhanced Primary Sludge Daily Operations Detail Continued

	Pilot Digester #3 - ClearCove Enhanced Primary Sludge																
	Feed Flow	Feed pH	Feed TS	TS Load	Feed VS	VS Load	MD Volume	Digester Temperature	Digester pH	Digester VS Load	Digester TS	Digester VS	VS destroyed	BIOGAS FLOW	Methane	Applied Production (CH4/VS fed)	Destroyed Production (CH4/VS rem)
Date	L/day	s.u.	%	lb/day	%	lb/day	gal	deg F	s.u.	lb/kcf/d	%	%	lb/day	sL/day	%	scfd/lb	scfd/lb
8/18/2014	17	5.2	3.5	1.30	68.8	0.89	100	95.6	7.1	67	1.8	66.7	0.45	98	62	2.4	4.8
8/19/2014	17	5.7	2.5	0.93	74.0	0.69	100	95.6	7.4	51	1.2	65.1	0.40	191	70	6.9	11.9
8/20/2014	17	5.2	2.6	0.96	73.4	0.71	100	97.0	7.0	53	1.2	65.9	0.41	180	64	5.8	9.8
8/21/2014	17		2.3	0.85	64.9	0.55	100	97.4	6.9	41	0.8	62.5	0.37	243	82	12.7	19.2
8/22/2014	17	5.5	1.9	0.70	70.3	0.49	100	96.8	7.3	37	1.4	66.5	0.15	284	64	13.0	42.9
8/23/2014	17			0.75		0.54	100	96.6	7.3	40				333	68	14.8	
8/24/2014	17			0.75		0.54	100	96.5	7.2	40				388	66	16.7	
8/25/2014	17		1.5	0.56	75.8	0.42	100	96.1	7.2	32	1.3	61.4	0.13	305	64	16.4	55.0
8/26/2014	31	5.2	2.2	1.51	67.1	1.01	100	96.4	7.1	76	1.2			335	70	8.2	
8/27/2014	31		2.6	1.78	73.6	1.31	100	97.9	7.2	98	2.4	63.3	0.27	328	72	6.4	30.9
8/28/2014	31	5.1	1.4	0.96	74.4	0.71	100	96.8	7.2	53	0.8	63.2	0.38	236	72	8.4	15.8
8/29/2014	31	6.1		1.38		1.00	100	97.8	7.3	75				294	72	7.5	
8/30/2014	31			1.38		1.00	100	96.8	7.2	75				290	70	7.2	
8/31/2014	31			1.38		1.00	100	97.7	7.2	75				214	72	5.4	
9/1/2014	31			1.38		1.00	100	97.6	7.3	75				217	70	5.4	
9/2/2014	16	5.1	2.1	0.74	76.5	0.57	100	97.5	7.2	43	1.0	59.7	0.36	341	72	15.2	24.2
9/3/2014	11		1.3	0.32	78.3	0.25	100	97.1		18	1.2	60.3	0.07	291	70	29.2	100.9
9/4/2014	24	5.0		1.07		0.77	100	96.4	7.0	58				308	74	10.4	
9/5/2014	13	6.3		0.56		0.41	100	98.1	7.0	31				323	70	19.6	
9/6/2014	14	6.2		0.60		0.44	100	98.0	7.1	33				211	70	12.0	
9/7/2014	13			0.56		0.41	100	98.1	7.2	31				206	72	12.8	
9/8/2014	14			0.60		0.44	100	97.9	7.3	33	1.0	58.1	0.27	205	70	11.6	18.8
9/9/2014	20	6.9	1.8	0.80	68.9	0.55	100	96.4	7.3	41				204	70	9.2	
9/10/2014	15			0.68		0.49	100	96.4	7.1	37				223	72	11.6	
9/11/2014	26	6.4	1.7	0.96	62.6	0.60	100	97.3	7.1	45	1.1	60.1	0.23	192	72	8.1	21.3
9/12/2014	22		1.0	0.49	68.3	0.33	100	97.4	7.1	25	1.0	61.5	0.03	170	74	13.4	130.5
9/13/2014	25			1.13		0.82	100	94.1	7.1	61				152	72	4.7	
9/14/2014	25			1.13		0.82	100	91.7	7.1	61				160	72	5.0	
9/15/2014	24			1.05		0.76	100	91.0	7.2	57				120	74	4.1	
9/16/2014	25	6.8	1.2	0.67	58.5	0.39	100	93.8	7.3	29	1.1	56.2	0.05	116	78	8.1	62.5
9/17/2014	22		1.1	0.53	65.7	0.35	100	97.4	7.3	26	0.8	53.3	0.15	73	74	5.5	12.4
9/18/2014	22	6.4	1.2	0.58	67.2	0.39	100	97.0	7.5	29	1.0	50.9	0.15	119	74	8.0	20.5
9/19/2014	22			0.98		0.71	100		7.3	53					72		
9/20/2014	22			0.98		0.71	100		7.1	53					74		
9/21/2014	22			0.98		0.71	100		7.2	53					72		
9/22/2014	17			0.73		0.53	100	96.4	7.3	40				12	74	0.6	
9/23/2014	18	5.5	1.2	0.47	67.2	0.32	100	97.7	7.4	24	0.7	49.8	0.18	51	74	4.2	7.1
9/24/2014	23			1.02		0.74	100	98.3	7.3	55				38	72	1.3	
9/25/2014	26	5.6	2.4	1.39	64.2	0.89	100	96.9	7.4	67	0.6	50.7	0.73	86	76	2.6	3.0
9/26/2014	25			1.13		0.82	100	97.9	7.3	61				155	74	4.9	
9/27/2014	19	5.5		0.83		0.60	100	97.4	7.5	45				187	72	7.9	
9/28/2014	25			1.13		0.82	100	96.3		61				92		2.8	
9/29/2014	25			1.13		0.82	100	97.3	7.3	61				56	70	1.7	
9/30/2014	28	5.5	2.0	1.23	67.7	0.83	100	95.9	7.4	62	0.5	48.2	0.69	14	74	0.4	0.5
10/1/2014	19			0.86		0.63	100	94.7	7.2	47				49	75	2.1	
10/2/2014	25	5.8	1.4	0.78	73.6	0.58	100	96.1	7.4	43	0.5	47.1	0.44	87	72	3.8	5.0
10/3/2014	25			1.13		0.82	100	96.0	7.2	61				132	78	4.5	
10/4/2014	23			1.03		0.75	100	96.0	7.3	56				144	72	4.9	
10/5/2014	22			1.01		0.73	100	96.3	7.3	55				178	70	6.0	
10/6/2014	25			1.09		0.79	100	96.7	7.2	59				192	72	6.2	
10/7/2014	22		1.7	0.82	73.6	0.61	100	97.5	7.1	45	1.0	61.5	0.31	212	72	8.9	17.3
10/8/2014	21			0.94		0.68	100	97.7	7.1	51				128	72	4.8	
10/9/2014	22			1.01		0.73	100	96.7	7.4	55				163	72	5.7	
10/10/2014	22			1.01		0.73	100	96.9	7.3	55				181	74	6.5	
10/11/2014	22			1.01		0.73	100	94.8		55				162	70	5.5	
10/12/2014	22			1.01		0.73	100	93.4		55				141		4.8	
10/13/2014	27			1.20		0.87	100	95.0	7.0	65				208	72	6.1	
10/14/2014	27			1.20		0.87	100	95.7	7.1	65				98	70	2.8	
10/15/2014	22			1.01		0.73	100	96.4	7.2	55				158	70	5.3	
10/16/2014	22			1.01		0.73	100	96.1	7.2	55				89	70	3.0	
10/17/2014	30			1.35		0.98	100	95.8	7.1	73				103	70	2.6	
10/18/2014	22			1.01		0.73	100	95.0	7.2	55				137	70	4.6	
10/19/2014	22			1.01		0.73	100	95.3		55				111		3.8	
10/20/2014	22			1.01		0.73	100	96.6	7.2	55				184	70	6.2	
10/21/2014	22			1.01		0.73	100		7.2	55					70		
10/22/2014	22			1.01		0.73	100		7.2	55					70		
	8/18-10/22																
Average	22	SRT	1.8	0.90	70	0.63	100	96.4		47	1.1	59	0.32	180	71	7.20	29.53
Sum	1,469	17.0											51%			4.67	32.53
Vol	379															29.16	130.48
# Rxn	3.9															7.30	19.02
# data pts	66															0.45	0.53
														methane	129	112	22
	All SCP																
	51	SRT	1.6	1.80	74	1.34	249	96.2		40	1.5	61	0.29	465	72	8.38	28.29
	6,043	18.4											22%			4.29	28.44
	943															29.16	130.48
	6.4															7.76	19.23
	59															0.45	0.53
														methane	334	157	33

Pilot Digester #4 – ClearCove Enhanced Primary Sludge 2x Daily Operations Detail

	Pilot Digester #4/2B - ClearCove Enhanced Primary Sludge x2																
	Feed Flow	Feed pH	Feed TS	TS Load	Feed VS	VS Load	MD Volume	Digester Temperature	Digester pH	Digester VS Load	Digester TS	Digester VS	VS destroyed	BIOGAS FLOW	Methane	Applied Production (CH4/VS fed)	Destroyed Production (CH4/VS rem)
Date	L/day	s.u.	%	lb/day	%	lb/day	gal	deg F	s.u.	lb/kcf/d	%	%	lb/day	sL/day	%	scfd/lb	scfd/lb
9/3/2014	39		2.4	2.06	75.0	1.55	100	97.1		116	1.8	60.8	0.61	260	72	4.3	10.9
9/4/2014	38	5.6		1.52		1.06	100	96.7	7.0	79				374	74	9.2	
9/5/2014	21	6.7		0.82		0.57	100	98.2	7.1	42				400	70	17.4	
9/6/2014	22	6.7		0.86		0.60	100	97.8	7.0	45				359	68	14.4	
9/7/2014	21			0.84		0.58	100	97.2	7.3	44				392	66	15.7	
9/8/2014	22			0.86		0.60	100	97.2	7.2	45	1.3	61.5	0.22	380	68	15.3	42.3
9/9/2014	21	6.8	1.9	0.90	68.4	0.61	100	95.8	7.3	46	0.7	52.5	0.45	374	70	15.1	20.6
9/10/2014	24			0.94		0.66	100	96.2	7.1	49				299	68	11.0	
9/11/2014	51	6.8	1.7	1.92	65.5	1.26	100	96.8	7.2	94	0.7	53.0	0.82	252	72	5.1	7.9
9/12/2014	42		1.5	1.40	67.8	0.95	100	96.4	7.1	71	1.4	61.3	0.15	323	72	8.7	55.7
9/13/2014	36			1.42		0.99	100	94.5	7.1	74				394	70	9.9	
9/14/2014	34			1.33		0.93	100	93.7	7.1	69				451	70	12.1	
9/15/2014	39			1.55		1.07	100	92.0	7.2	80				352	72	8.3	
9/16/2014	45	6.9	1.6	1.60	63.6	1.02	100	95.5	7.3	76	0.9	51.0	0.57	269	74	6.9	12.3
9/17/2014	48		1.2	1.26	72.6	0.91	100	95.7	7.2	68	1.6	62.5	-0.14	273	70	7.4	
9/18/2014	45	6.6	1.2	1.20	70.1	0.84	100	95.3	7.2	63	1.1	58.5	0.20	321	70	9.4	40.1
9/19/2014	43			1.72		1.19	100		7.1	89					70		
9/20/2014	45			1.80		1.25	100		7.1	94					70		
9/21/2014	45			1.80		1.25	100		7.1	94					68		
9/22/2014	49			1.93		1.34	100	96.4	7.1	100				454	66	7.9	
9/23/2014	45	6.3	1.6	1.60	71.8	1.15	100	97.6	7.2	86	0.8	55.4	0.73	351	66	7.1	11.2
9/24/2014	48			1.89		1.31	100	98.0	7.0	98				330	62	5.5	
9/25/2014	44	7.5	3.2	3.13	72.0	2.25	100	97.2	7.1	169	1.3	66.0	1.41	368	66	3.8	6.1
9/26/2014	30			1.20		0.84	100	97.3	7.1	63				378	66	10.6	
9/27/2014	45	6.1		1.80		1.25	100	97.6	7.4	94				356	58	5.8	
9/28/2014	45			1.80		1.25	100	96.7		94				454		8.3	
9/29/2014	48			1.89		1.31	100	98.1	6.9	98				483	62	8.1	
9/30/2014	49	5.9	1.7	1.82	76.2	1.39	100	96.0	7.0	104	2.4	68.7	-0.38	421	64	6.8	
10/1/2014	42			1.65		1.15	100	94.9	6.8	86				504	60	9.3	
10/2/2014	42	6.3	2.1	1.95	64.8	1.27	100	96.5	6.9	95	1.5	60.9	0.42	469	56	7.3	22.3
10/3/2014	40			1.59		1.11	100	96.2	7.0	83				425	58	7.9	
10/4/2014	47			1.85		1.28	100	96.5	7.3	96				524	56	8.1	
10/5/2014	45			1.80		1.25	100	96.3	7.3	94				416	64	7.5	
10/6/2014	49			1.93		1.34	100	96.5	7.1	100				410	62	6.7	
10/7/2014	45	6.4	1.5	1.50	66.8	1.00	100	97.3	7.0	75	1.5	51.4	0.23	557	64	12.6	54.5
10/8/2014	48			1.89		1.31	100	97.5	6.9	98				575	62	9.6	
10/9/2014	40			1.59		1.11	100	96.7	7.2	83				425	60	8.1	
10/10/2014	40			1.59		1.11	100	96.6	7.1	83				475	60	9.1	
10/11/2014	40			1.59		1.11	100	94.4		83				491	62	9.7	
10/12/2014	40			1.59		1.11	100	93.7		83				581		12.1	
10/13/2014	44			1.76		1.22	100	94.9	6.9	92				420	62	7.5	
10/14/2014	43	6.2		1.72		1.19	100	95.5	7.0	89				388	62	7.1	
10/15/2014	40			1.59		1.11	100	96.2	7.1	83				324	60	6.2	
10/16/2014	40			1.59		1.11	100	95.9	7.2	83				255	62	5.0	
10/17/2014	40			1.59		1.11	100	95.2	7.2	83				367	62	7.3	
10/18/2014	40			1.59		1.11	100	93.8	7.2	83				327	60	6.3	
10/19/2014	40			1.59		1.11	100	94.2	7.1	83				252		5.2	
10/20/2014	43			1.72		1.19	100	96.5		89				463	60	8.2	
10/21/2014	44	6.4		1.76		1.22	100		7.2	92					62		
10/22/2014	40			1.59		1.11	100		6.7	83					64		
	9/3-10/22																
Average	40	SRT	1.8	1.60	70	1.11	100	96.1		83	1.3	59	0.43	394	65	8.77	25.80
Sum	2,022	9.4											39%			3.13	18.86
Vol	379															17.42	55.65
# Rxn	5.3															8.08	20.65
# data pts	50															3.81	6.07
														methane	257	45	11

Appendix F. Mass Balance Detail

EXISTING PLANT FLOW STREAMS

HISTORICAL MASS BALANCE
(Jan 2013 - September 2014)

Parameter:	Raw Inf	Return	PC Inf	PC Eff	RAS	AT Eff	SC Eff	Final Eff	Raw S	PC Eff	WAS	B/W	Th Feed	Th S	Th O/F	Truck	PDS	Dig S	Decant	Cake	Filtrate
Flow, MGD	6.4	2.4	8.8	7.65	6.05	13.7	7.26	6.40	0.43	0.72	0.39	0.86	2.4	0.06	2.34		0.061	0.022	0.040	0.0035	0.018
TSS, mg/L	153	1,340	477	108	3,600	1,705	14	6	7,640	108	3,600	74	2,010	34,800	1,150		21,900	39,700	12,100	238,000	1,990
lb/day	8,200	26,800	35,000	6,900	182,000	195,000	850	320	27,400	650	11,700	530	40,300	17,800	22,500		11,200	7,200	4,000	6,900	300
Removal, %				16%			90%	96%													
VSS, mg/L	136	940	356	96	2,920	1,380	12	5	5,450	96	2,920	66	1,500	25,400	880		10,990	22,400	4,820	132,240	1,130
lb/day	7,300	18,800	26,100	6,100	147,000	158,000	730	260	19,500	580	9,500	470	30,100	13,000	17,100		5,630	4,030	1,600	3,860	170
Removal, %				16%			90%	96%													
VSS:TSS ratio	89%	70%	75%	89%	81%	81%	86%	80%	71%	89%	81%	89%	75%	73%	77%		50%	56%	40%	56%	57%
BOD5, mg/L	151			106			15	12													
lb/day	8,100			6,800			910	640													
Removal, %				16%			89%	92%													
TKN, mg/L	28			30																	
NH_3-N, mg/L	18																				
TP, mg/L	3.7			2.6																	
DO, mg/L						2.3									7.8						
Airflow, scfm						2,090															
Temperature, F	64							63													
SRT, Days											1.4										
VS Destruction																	57%				
Total Methane, scfd																		57,141			
Sludge, dry tons/day																				3.5	

FUTURE FLOW STREAM - ENHANCED PRIMARY CLARIFICATION

ENHANCED PRIMARY CLARIFICATION & SCP UPGRADE MASS BALANCE

Parameter:	Raw Inf	Return	EPT Inf	EPT Eff	RAS	AT Eff	SC Eff	Final Eff	Raw S	WAS	B/W	Th Feed	SCP S	SCP Decant	Truck	PDS	Dig S	Decant	Cake	Filtrate
Flow, MGD	6.4	0.12	6.5	6.4	4.0	10.4	6.3	6.2	0.11	0.13	0.00	0.00	0.05	0.06		0.050	0.022	0.028	0.0035	0.018
TSS, mg/L	237	5,196	329	53	3,600	1,705	14	6	16,400	3,600	0	0	28,000	5,990		13,200	19,400	8,400	113,000	1,320
lb/day	12,700	5,200	17,900	2,854	120,000	148,000	730	310	15,046	3,900	0	0	11,686	2,996		5,500	3,500	2,000	3,300	200
Removal, %				78%			94%	98%												
VSS, mg/L	195	2,544	238	36	2,920	1,380	12	5	11,990	2,920	0	0	21,600	3,550		6,500	10,300	3,400	60,000	660
lb/day	10,408	2,546	12,954	1,937	97,000	120,000	630	260	11,000	3,200	0	0	9,000	1,776		2,700	1,850	800	1,750	100
Removal, %				81%			94%	98%		0										
VSS:TSS ratio	82%	49%	72%	68%	81%	81%	86%	83%	73%	81%	0%	0%	77%	59%		49%	53%	40%	53%	50%
BOD5, mg/L	171			43			15	12												
lb/day	9,102			3,004			790	620												
Removal, %				67%			91%	93%												
TKN, mg/L	28			21												6371				
NH_3-N, mg/L	18																			
TP, mg/L	3.7			0.89																
DO, mg/L						2.0														
Airflow, scfm																				
Destructive Yield													29.3							
Applied Yield																				
SRT, Days										17.2										
VS Destruction																70%				
Methane, scfd																	184,590			
Sludge, dry tons/day																			1.7	

Appendix G. Data Quality Detail

Date	Plant TS FT-1 %	Lab TS FT-1 %	Plant VS FT-1 %	Lab VS FT-1 %	Plant TS MD-1 %	Lab TS MD-1 %	Plant VS MD-1 %	Lab VS MD-1 %
4/14/2014		3.2		71.3		4.6		56.3
4/18/2014		3.0		71.8		4.3		57.0
4/21/2014		2.7		70.6		4.6		58.5
4/22/2014	3.1							
4/23/2014		3.5		74.8		4.4		58.1
4/24/2014	3.1		74.1		3.9		58.8	
4/25/2014	3.2		75.2					
4/28/2014	2.9	3.4	74.2	75.2	2.9	3.9	61.4	58.1
4/29/2014	2.8		71.4					
4/30/2014	2.8	3.0	71.4	72.1	3.8	4.5	64.0	58.6
5/1/2014	3.1	0.83	71.4		4.4	3.3	60.8	
5/2/2014		3.1		67.8		3.1		56.2
5/5/2014	3.2	3.2	68.4	69.0	2.5	2.6	56.9	56.0
5/6/2014	3.0		67.6		2.7		56.7	
5/7/2014	2.9	3.0	67.2	66.6	2.8	2.9	58.3	57.0
5/8/2014	2.8		66.9		2.8		57.8	
5/12/2014	2.8	2.2	69.9	70.5	0.43	0.41	57.9	52.4
5/14/2014	1.9	1.9	70.1	66.9	0.32	1.5	51.8	59.8
5/15/2014	1.8		67.6		0.32		47.3	
5/16/2014	1.7		64.3					
6/2/2014	1.8		63.6		0.32		53.2	
6/17/2014	2.9		72.4					
6/26/2014	2.3							
7/8/2014	4.1		55.4		1.1			
7/9/2014	1.7		62.2		1.1		57.1	
7/10/2014	1.6		62.3		1.1		54.3	
7/11/2014	2.1		65.0		0.78		54.2	
7/14/2014	4.6		61.0		0.70		57.3	
7/15/2014	2.6		65.5		1.6		58.8	
7/16/2014	1.8		67.1		0.69		58.2	
7/21/2014	1.1		66.7		0.40		56.8	
7/23/2014		1.1		59.7	1.5	0.32	59.1	49.6
7/24/2014	1.2		62.7					
7/28/2014	0.87	0.79	60.3	59.5	0.63	1.4	61.6	59.7
7/30/2014	2.1	2.1	68.9	68.9	1.4	2.5		54.4
7/31/2014	4.5		62.1		2.3			
8/1/2014		1.5		67.8		1.5		55.9
8/4/2014	2.8	1.9	59.0	64.0	1.2	0.48	58.7	52.5
8/5/2014	1.9		67.1					
8/6/2014		5.6	60.2	65.6	1.5	1.5	60.4	58.3
8/7/2014	1.5		63.6		1.5		59.3	
8/8/2014		2.2		64.0		1.2		59.0
8/11/2014		3.7		61.2		1.4		56.1
8/12/2014	2.9		61.3		0.74		54.1	
8/13/2014	3.5		64.4		1.3		54.0	
8/14/2014	1.3	3.9	63.2	63.8	2.2	1.8	57.7	55.3
8/15/2014	1.9	1.4	63.1	63.8	1.6	1.7	58.7	55.3
8/18/2014	3.3	4.2	61.4	61.3	1.5	1.6	57.4	55.1
8/19/2014	3.0		62.3		2.0		56.6	
8/20/2014	3.0	2.8	62.9	64.0	1.9	1.5	56.7	58.1
8/21/2014	3.0		62.3		0.52		51.6	
8/22/2014	3.2	3.2	63.1	60.6	1.3	1.3	59.9	56.8
8/25/2014	2.1		62.8	60.8	2.0	2.0	58.3	57.2
8/26/2014	1.2		67.2		2.8		58.0	
8/27/2014	0.65	0.64	59.6	60.5		2.2		57.5
8/28/2014	0.90		68.5		1.5		58.7	
8/29/2014		0.79		61.9		2.7		56.4
9/1/2014		1.0		67.0		1.5		55.4
9/2/2014	1.3		60.3		1.2		57.7	
9/3/2014	3.1	3.2	60.4	58.7	1.4	1.5	59.2	56.7
9/5/2014		1.0		60.2		1.6		58.2
9/8/2014		1.8		58.8	1.4	1.4	57.8	58.7
9/9/2014	1.4		61.6		0.67		57.4	
9/10/2014		2.8		57.7		1.6		59.0
9/11/2014	0.83		61.8		1.1		61.0	
9/12/2014	0.57	0.68	61.5	57.9	1.1	1.1	61.7	59.1
Average	2.3	2.4	65	65	1.6	2.2	58	57
std dev	1.0	1.2	4.4	5.1	1.0	1.2	3.1	2.2
95% Confidence	0.27	0.41	1.2	1.7	0.29	0.42	0.93	0.76
Minimum	0.57	0.64	55	58	0.32	0.32	47.3	50
Median	2.6	2.7	64	64	1.4	1.6	58	57
Maximum	4.6	5.6	75	75	4.4	4.6	64	60
# data pts	51	33	50	33	45	34	42	33

	Plant	Lab	Plant	Lab	Plant	Lab	Plant	Lab
	TS	TS	VS	VS	TS	TS	VS	VS
	FT-2A	FT-2A	FT-2A	FT-2A	MD-2A	MD-2A	MD-2A	MD-2A
Date	%	%	%	%	%	%	%	%
4/14/2014		1.1		78.0		3.8		57.2
4/18/2014	0.45	0.35		67.6		4.0		56.7
4/21/2014		0.85		78.2		4.0		56.8
4/22/2014	1.4		82.4					
4/23/2014		0.86		79.0		4.0		56.3
4/24/2014	1.3		84.1		4.1		58.9	
4/25/2014	2.0		83.9					
4/28/2014	2.2	1.2	75.2	75.7		4.1		59.8
4/29/2014	1.7		78.4					
4/30/2014	2.1	2.2	74.2	73.1				
5/1/2014	1.8	3.1	79.1					
5/2/2014		3.4		57.1				
5/5/2014	1.9	1.7	54.2	59.5	2.7	1.6	60.8	60.7
5/6/2014	1.8		58.5		2.1		60.2	
5/7/2014	1.6	1.7	60.6	59.8	2.0	1.6	59.1	59.8
5/8/2014	1.6		62.1		3.9		57.9	
5/12/2014	1.9	1.5	55.8	68.0	3.6	4.5	58.9	56.3
5/14/2014	2.0	2.4	75.4	69.5	1.1	1.4	68.9	58.2
5/15/2014	2.7		68.2		2.7		63.4	
5/16/2014	2.5		68.7					
6/2/2014	3.7		66.9		2.3		66.3	
6/17/2014	1.9		82.8					
6/26/2014	2.5							
7/8/2014	2.4		74.1		0.90		61.5	
7/9/2014	1.9		71.4		1.1		69.8	
7/10/2014	1.8		71.9		0.82		64.6	
7/11/2014	2.0		73.4		0.81		64.4	
7/14/2014	2.0		68.7		1.2		64.7	
7/15/2014	2.0		67.4		0.46		63.3	
7/16/2014	1.7		73.2		0.38		62.1	
7/21/2014	1.2		76.9		1.1		65.7	
7/23/2014	1.1	1.3	74.0	75.7	0.64	1.0	66.5	65.6
7/24/2014	1.2		75.3		1.5		69.4	
7/28/2014	1.5	1.5	77.8	76.9	1.1	1.1	62.7	65.0
7/30/2014	1.4	1.5	79.8	77.9	1.0	1.0	69.4	69.0
7/31/2014					1.5			
8/1/2014		2.4		65.9		1.2		71.8
8/4/2014		2.5		67.7	1.3	1.0	71.7	65.6
8/5/2014	2.3		75.7		1.5		72.3	
8/6/2014	2.7	2.6	76.2	68.0	1.7	2.0	70.8	59.1
8/7/2014	1.3		74.0		1.9		67.2	
8/8/2014		0.72		72.7		1.7		62.8
8/11/2014		1.6		59.5		1.6		63.8
8/12/2014	3.5		61.0		1.5		65.9	
8/13/2014	2.7		57.0		1.8		55.3	
8/14/2014	1.9	2.4	63.6	56.5	0.83	2.4	66.2	60.7
8/15/2014	1.6	1.6	62.0	56.5	3.2	2.4	65.6	60.7
8/18/2014	3.7	3.4	60.1	61.6		1.8		63.1
8/19/2014	2.8		69.7		2.2		58.1	
8/20/2014	3.0	3.9	63.1	68.2	2.3	1.6	57.3	56.5
8/21/2014	3.2		68.1		2.2		55.3	
8/22/2014	2.1	2.1	71.5	69.1	1.7	1.7	58.7	54.8
8/25/2014	1.8	1.8	67.9	64.3	1.4	1.4	58.2	57.8
8/26/2014	1.2		72.6		1.2		59.2	
8/27/2014	0.78	0.85	70.0	69.0	1.6	1.6	54.9	55.6
8/28/2014	0.94		72.4		1.0		59.7	
8/29/2014		0.78		66.5		1.3		57.2
9/1/2014		1.2		62.1		1.1		55.5
Average	2.0	1.8	71	68	1.7	2.1	63	60
std dev	0.71	0.90	7.8	7.1	0.91	1.2	4.9	4.4
95% Confidence	0.20	0.33	2.18	2.63	0.29	0.44	1.58	1.70
Minimum	0.45	0.35	54	57	0.38	1.00	55	55
Median	1.9	1.6	73	68	1.5	1.6	63	59
Maximum	3.7	3.9	85	79	4.1	4.5	72	72
# data pts	51	29	49	28	38	26	37	26

Date	Plant	Lab	Plant	Lab	Plant	Lab	Plant	Lab
	TS	TS	VS	VS	TS	TS	VS	VS
	FT-3	FT-3	FT-3	FT-3	MD-3	MD-3	MD-3	MD-3
	%	%	%	%	%	%	%	%
4/14/2014		0.56		75.6		4.1		55.4
4/18/2014		1.2		79.4		3.0		54.3
4/21/2014		1.2		79.8		2.9		55.5
4/22/2014	1.1							
4/23/2014	0.7	1.1		78.3		3.9		55.1
4/24/2014	1.0		77.7		3.7		55.8	
4/25/2014	1.9		83.6					
4/28/2014	1.6	1.3	84.0	81.5	5.0	4.6	54.5	54.0
4/29/2014	1.5		82.7					
4/30/2014	1.0	1.3	84.5	80.2	1.3	1.2	76.7	66.5
5/1/2014	1.8	1.8	84.1		1.5	1.9	73.2	
5/2/2014		1.3		74.2		1.1		65.2
5/5/2014	1.1	0.97	76.4	76.0	2.4	1.2	64.2	62.8
5/6/2014	1.2		77.3		0.94		65.1	
5/7/2014	1.0	1.3	70.5	78.0	1.8	0.84	66.0	63.5
5/8/2014	1.6		76.6		2.8		64.9	
5/12/2014	2.8	3.1	77.2	74.1	1.0	0.75	69.6	62.7
5/14/2014	2.1	2.8	80.8	73.5	0.67	0.68	76.0	63.9
5/15/2014	3.0		74.3		1.9		68.0	
5/16/2014	2.3		76.0					
6/2/2014	1.3		80.2		3.5		61.0	
6/17/2014	2.5		76.9					
6/26/2014	1.7							
7/8/2014	2.1		73.1		0.98		60.3	
7/9/2014	2.0		80.9		1.3		71.1	
7/10/2014	1.8		77.7		1.3		69.2	
7/11/2014	1.7		77.6		1.2		67.6	
7/14/2014	2.1		77.4		1.0		71.2	
7/15/2014	2.0		78.4				65.4	
7/16/2014	1.9		79.8		1.2		71.6	
7/21/2014	1.8		77.3		1.5		67.5	
7/23/2014		1.3		74.5	0.79	0.78	76.4	71.2
7/24/2014	2.9		81.0		1.4		77.1	
7/28/2014	3.7	3.8	80.8	79.7	1.5	1.6	77.9	75.4
7/30/2014	2.3	2.3	79.9	79.4	2.2	2.2	78.4	77.0
7/31/2014					2.3			
8/1/2014		1.9		63.4		1.8		76.7
8/4/2014		3.2	71.6	68.9	2.5	1.8	75.4	72.4
8/5/2014	2.0		79.3		2.3		77.8	
8/6/2014	1.8	2.8	76.7	77.2	2.6	2.0	77.5	75.1
8/7/2014	1.3		71.6		1.6		75.0	
8/8/2014		1.5		73.5		1.6		74.1
8/11/2014		2.2		66.3		1.9		68.2
8/12/2014	1.9		64.1		1.7		66.8	
8/13/2014	2.7		66.3		2.0		66.5	
8/14/2014	2.7	3.6	55.8	66.0	2.2	2.1	68.2	66.9
8/15/2014	1.3	1.2	74.2	66.0	2.2	2.3	70.4	66.9
8/18/2014	3.5	2.5	68.8	74.0	1.8	0.72	66.7	70.5
8/19/2014	2.5		74.0		1.2		65.1	
8/20/2014	2.6	2.4	73.4	73.6	1.2	1.4	65.9	69.9
8/21/2014	2.3		64.9		0.81		62.5	
8/22/2014	1.9	2.1	70.3	66.1	1.4	1.4	66.5	62.3
8/25/2014	1.5	1.5	75.8	74.3	1.3	1.3	61.4	58.9
8/26/2014	2.2		67.1		1.2			
8/27/2014	2.6	2.7	73.6	72.5	2.4	2.4	63.3	63.4
8/28/2014	1.4		74.4		0.77		63.2	
8/29/2014		0.84		70.2		2.8		64.1
9/1/2014		1.3		72.7		1.1		57.4
9/2/2014	2.1		76.5		1.0		59.7	
9/3/2014	1.3	1.3	78.3	76.8	1.2	1.2	60.3	56.3
9/5/2014		1.3		75.2		0.99		60.9
9/8/2014		1.5		62.6	0.96	0.97	58.1	58.4
9/9/2014	1.8		68.9					
9/10/2014		1.4		65.1		0.53		50.8
9/11/2014	1.7		62.6		1.1		60.1	
9/12/2014	1.0	1.1	68.3	65.6	1.0	0.63	61.5	51.0
Average	1.9	1.8	74	72	1.6	1.5	65	61
std dev	0.7	0.77	6.5	5.7	0.86	1.0	8.3	8.4
95% Confidence	0.16	0.23	1.65	1.71	0.23	0.29	2.23	2.52
Minimum	0.70	0.56	56	58	0.49	0.53	47	48
Median	1.8	1.5	76	74	1.3	1.2	66	62
Maximum	3.7	3.8	85	82	5.0	4.6	78	77
# data pts	63	44	59	43	54	44	53	43

	Plant	Lab	Plant	Lab	Plant	Lab	Plant	Lab
	TS	TS	VS	VS	TS	TS	VS	VS
	FT-4/2B	FT-4/2B	FT-4/2B	FT-4/2B	FT-4/2B	FT-4/2B	FT-4/2B	FT-4/2B
Date	%	%	%	%	%	%	%	%
4/14/2014		0.69		77.8		4.5		56.5
4/18/2014		0.64		75.4		5.0		57.5
4/21/2014		1.2		81.8		4.9		58.2
4/22/2014	1.0							
4/23/2014	0.80	0.87		79.2		4.5		59.3
4/24/2014	1.1		80.5		4.3		59.5	
4/25/2014	2.0		83.0					
4/28/2014	1.8	1.7	82.9	82.9	2.6	4.3	65.8	58.8
4/29/2014	1.7		83.1					
4/30/2014	1.8	1.2	85.0	78.6	3.9	1.1	66.2	65.7
5/1/2014	1.7	1.3	82.9		1.2	1.4	70.1	
5/2/2014		1.5		69.7		0.24		50.4
5/5/2014	1.9	1.8	74.9	75.5	1.6	0.47	64.3	56.9
5/6/2014	1.6		77.2		0.91		64.2	
5/7/2014	1.2	2.3	78.3	79.7	0.67	0.55	61.5	59.6
5/8/2014	2.0		74.6		2.0		64.2	
5/12/2014	3.4	2.8	70.1	78.0	1.1	1.0	70.0	65.5
5/14/2014	2.8	2.9	80.1	77.4	1.3	1.6	67.9	64.3
5/15/2014	3.1		72.5		1.8		69.1	
5/16/2014	3.1		70.4					
6/2/2014	1.4		81.1		1.4		65.9	
6/17/2014								
6/26/2014	2.0							
7/8/2014	1.8		78.2		0.76		60.1	
7/9/2014	3.5		61.5		1.1		65.1	
7/10/2014	3.6		54.9		1.2		64.2	
7/11/2014	2.1		71.6		1.4		61.9	
7/14/2014	1.7		78.7		0.97		66.5	
7/15/2014	1.7		79.9		0.37		69.2	
7/16/2014	1.3		79.4		1.1		67.6	
7/21/2014	1.7		77.3		0.37		66.0	
7/23/2014	1.7	1.5	76.4	76.6	0.41	0.82	70.1	68.5
7/24/2014	1.7		77.9		0.74		70.5	
7/28/2014	2.1	2.4	81.3	80.5	1.6	1.6	76.7	75.5
7/30/2014	1.6	1.7	81.0	80.2	1.4	1.4	75.8	74.6
7/31/2014			81.0					
8/1/2014		1.5		71.5		1.3		67.5
8/4/2014	3.6	2.9	73.9	76.2	0.91	6.0	74.0	75.1
8/5/2014	1.6		82.0		2.0		76.0	
8/6/2014	3.8	2.9	75.7	75.9	1.6	1.4	78.9	70.9
8/7/2014	1.7		72.1		1.3		73.7	
8/8/2014		2.0		76.5		1.3		73.7
8/11/2014		2.3		63.5				
8/12/2014					1.7		61.0	
8/13/2014	3.2				1.7		62.6	
8/14/2014	1.3	2.1	68.0	55.6		1.8	64.4	62.4
8/15/2014	2.6	1.3	69.9	55.6	2.2	0.79	59.9	62.4
8/18/2014		1.7	68.4	74.2	1.4		66.9	62.7
8/19/2014	1.9		74.0		0.58		59.2	
8/20/2014	1.9	1.6	74.5	75.4	0.59	1.6	60.3	69.8
8/21/2014			65.6		1.5		70.5	
8/22/2014	1.6	1.6	70.7	65.6	1.7	1.6	71.7	64.6
8/25/2014	1.5	1.4	78.2	76.4	1.3	1.3	70.2	70.0
8/26/2014	1.7		75.3		1.6		70.4	
8/27/2014	2.2	2.4		52.8	1.7	1.8	68.6	69.6
8/28/2014								
8/29/2014								
9/1/2014								
9/2/2014	2.2		72.5		1.3		59.4	
9/3/2014	2.4	2.4	75.0	74.0	1.8	1.9	60.8	60.6
9/5/2014		1.9		68.0		1.3		63.5
9/8/2014		3.0		68.9	1.3	1.3	61.5	60.3
9/9/2014	1.9		68.4		0.67		52.5	
9/10/2014		1.7		67.7		1.4		59.0
9/11/2014	1.7		65.5		0.74		53.0	
9/12/2014	1.5	1.8	67.8	66.0	1.4	0.67	61.3	48.0
Average	2.0	1.8	74	72	1.4	1.8	65	63
std dev	0.7	0.60	6	7.3	0.73	1.4	6.4	6.3
95% Confidence	0.19	0.18	1.66	2.22	0.20	0.43	1.70	1.97
Minimum	0.80	0.64	55	53	0.37	0.24	51	48
Median	1.7	1.7	75	74	1.3	1.4	65	63
Maximum	3.8	3.0	85	83	4.3	6.0	79	76
# data pts	57	42	55	41	53	40	54	39

Appendix H. Energy Production Calculations

Appendix I - Energy Production Calaculations

IAWWTF Historical Current		EPT w/ Current IAWWTF Thickener		EPT w/ SCP		
Average Energy Cost ($/kWh)	$ 0.095	Average Energy Cost ($/kWh)	$ 0.095	Average Energy Cost ($/kWh)	$ 0.095	
Energy Consumption						
Aeration Energy for BOD Removal (k	3,100	Aeration Energy for BOD Removal (kWh/day)	1,500	Aeration Energy for BOD Removal (kWh/day)	1,500	
Aeration BOD Rem (kWh/Year)	1,131,500	Aeration BOD Rem (kWh/Year)	547,500	Aeration BOD Rem (kWh/Year)	547,500	
Total Aeration Energy Consumption	1,571,528	Total Aeration Energy Consumption (kWh/Year)	987,528	Total Aeration Energy Consumption (kWh/Year)	987,528	
Total Energy Consumption (kWh/Ye	3,274,016	Total Energy Consumption (kWh/Year)	2,690,016	Total Energy Consumption (kWh/Year)	2,690,016	
Total Energy Cost ($/Year)	$ 311,032	Total Energy Cost ($/Year)	$ 255,552	Total Energy Cost ($/Year)	$ 255,552	
Energy Production						
Lb/Day VS to Digester	13,000	Lb/Day VS to Digester	13,600	Lb/Day VS to Digester	9,000	From mass balance
VS Destruction	57%	VS Destruction	62%	VS Destruction	70%	Scaled from pilot digester results
Destructive Yield (scf CH4/lb VS des	7.7	Destructive Yield (scf CH4/lb VS destroyed)	12.5	Destructive Yield (scf CH4/lb VS destroyed)	29.3	From pilot digester results
Annual Methane Production (ft3)	20,841,500	Annual Methane Production (ft3)	38,544,000	Annual Methane Production (ft3)	67,375,350	
Microturbine Conversion Efficiency	35%	Microturbine Conversion Efficiency	35%	Microturbine Conversion Efficiency	35%	
Energy Produced (MBTU)	7,404	Energy Produced (BTU)	13,693	Energy Produced (BTU)	23,935	
Energy Produced (kWh)	2,169,972	Energy Produced (kWh)	4,013,117	Energy Produced (kWh)	7,014,975	
Value of Energy Produced	$ 206,147	Value of Energy Produced	$ 381,246	Value of Energy Produced	$ 666,423	
Net Energy						
Net Energy (kWh/year)	(1,104,045)	Net Energy (kWh/year)	1,323,101	Net Energy (kWh/year)	4,324,958	
Net Energy Value ($/year)	$ (104,884)	Net Energy Value ($/year)	$ 125,695	Net Energy Value ($/year)	$ 410,871	
GWH/YEAR	(1.10)		1.32		4.32	

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Energy Research and
Development Authority

17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov