

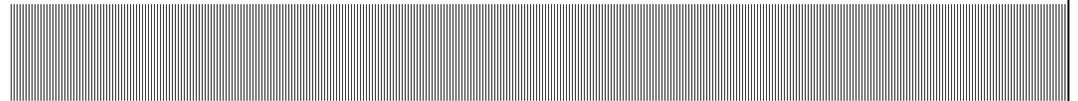


Groversville-Johnstown Joint Wastewater Treatment Plant
191 Union Avenue • Johnstown, New York 12095-3399

Sludge Disintegration Summary Report

PON No. 1171

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1. Introduction

1.1. Background Information

The Cities of Gloversville and Johnstown operate a joint wastewater treatment facility (WWTF) that historically treated domestic wastewater, landfill leachate, and industrial wastewater from leather tanning and finishing, textile corporations, and other major industries. The WWTF was designed to treat 13 million gallons per day (mgd) of wastewater using a conventional activated sludge process.

Over the past 20 years, the Gloversville-Johnstown area has experienced a dramatic change in its industrial base. For nearly a century, the leather tanning industry dominated the area and was the major employer. Due to foreign competition, environmental rules and regulations, and many other factors, these industries have experienced a major decline. The construction of Johnstown Industrial Park (Park) and subsequent marketing of the industrial building lots has provided the Gloversville-Johnstown area with a more diverse employment portfolio. The Calloway/Top Flite Golf Company, Benjamin Moore Paint Factory, the Wal-Mart Distribution Center and many other diverse companies now are situated in the locale providing jobs to local residents.

While many of these companies have not required significant wastewater treatment capacity, the addition of FAGE USA, Inc. (greek yogurt producer) and growth of Euphrates, Inc. (feta cheese producer) has added a tremendous burden on wastewater treatment facility's capacity. The food manufacturing sector generates highly concentrated wastewater that is difficult to treat efficiently.

The wastewater from the dairy processing facilities mainly consist of three components; domestic wastewater from administrative facilities, medium strength wastewater from washdown operations, and high strength whey, a byproduct of the production of cheese and yogurt. Whey is treated at the WWTF via mesophilic anaerobic digestion and the medium strength washdown water is pretreated in a dissolved air floatation thickener, with the float pumped to the digesters and the underflow pumped to the primary clarifier influent channel. The addition of the medium strength wastewater and whey has resulted in an increase in sludge production resulting in an increase in sludge disposal costs.

Malcolm Pirnie, Inc., the Water Division of ARCADIS, was retained by the WWTF to perform sludge disintegration pilot-scale testing to determine if the addition of sludge disintegration process would increase sludge dewaterability, and subsequently decrease the volume of sludge requiring off-site disposal. A Performance Monitoring Plan (PMP) was

written to develop the parameters to document and assess the performance of the sludge disintegration testing.

In the sludge disintegration process (also referred to as cell lysis) the cell walls are ruptured, enhancing microbial decomposition and biogas recovery. For this application, it was believed that sludge disintegration of either the primary digester feed or the secondary digester effluent would increase the total solids in the dewatered sludge cake by liberating water from cellular material and/or enhancing digestion of anaerobes produced by the recuperative thickening loop.

There are several types of processes that accomplish sludge disintegration. These processes are typically mechanical, pressure-based, chemical, thermal, ultrasonic, electrical, or a combination of these. For this application, electrical, mechanical and ultrasonic processes were determined to be the most plausible due to the size of the WWTF. Electric-based systems, such as OpenCel's® pulsed electronic technology, rely on cavitation to rupture the cell membrane. In the case of the OpenCel® technology, power input is dependent on the conductivity of the sludge. Since the WWTF's sludge has a higher than typical conductivity due to high concentrations of ionic salts from the dairy wastes, it was decided not to test the technology at pilot-scale. [Due to the high conductivity, the power required by the technology would negate the payback of the reduced cost of sludge disposal.]

Mechanical systems, such as Siemens' Crown Disintegration System® (Crown System), rely on shear to rupture the cell membrane. In particular, the shearing occurs as the sludge is pumped through a nozzle. It was decided to test the Crown system at pilot-scale due to its simplicity and scalability.

Ultrasonic systems, such as the Ovivo Sonolyzer Ultrasound Sludge Disintegration System® (Sonolyzer System), also rely on cavitation. Initially it was decided that the Sonolyzer System would be tested at pilot-scale. However, after completing the Crown System pilot test, it was determined that the Sonolyzer System was too small for the intended application and the pilot test was cancelled.

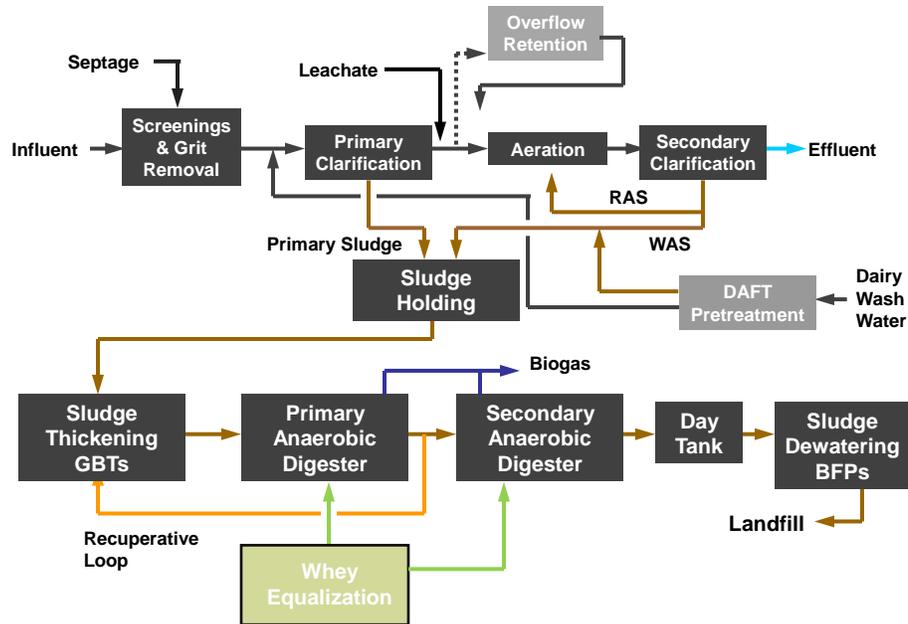
To compensate for not testing the Sonolyzer System, a third phase was added to the Crown System testing. Phase I was a two day pilot. After a rest of one week, Phase II was piloted for one month. And finally, after a rest of one month, Phase III was piloted for approximately two months.

The pilot proceeded following the outline of the PMP. Any deviation from the PMP is noted in the descriptions below.

1.1.1. Baseline Operation

A schematic of the typical WWTF operation processes is shown in Figure 1-1. Primary sludge, Waste Activated Sludge (WAS) and DAFT sludge are combined in the Sludge Holding Tank and then thickened in the Gravity Belt Thickeners (GBTs).

Figure 1-1. Block Diagram for Baseline Operation.



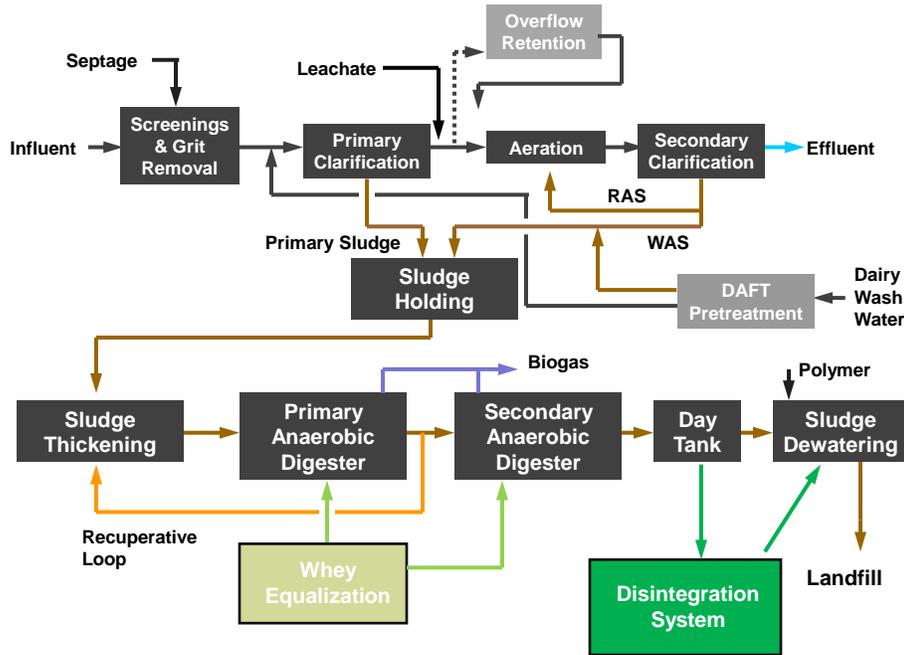
Thickened sludge is fed to the Primary Anaerobic Digester, where high strength dairy whey is co-digested. Effluent from the Primary Digester is returned to the GBTs through the recuperative thickening loop. Secondary Digester effluent is stored in a Day Tank and then fed to the Belt Filter Presses (BFPs) for final dewatering before landfill disposal.

During baseline operation a portion (approximately 20 percent) of the dairy whey was fed into the Secondary Digester. This operation continued through Phase I and Phase II.

1.1.2. Phase I - Secondary Digester Effluent Sludge Disintegration

During the first phase, digested sludge was processed through the disintegration unit prior to dewatering. In place of the originally-planned week long test period, this phase was performed for a period of two days. Digested sludge from the day tank was treated by the disintegration system at a rate of approximately 30 gpm, or 30 percent of the flow, at a thickness of 2.7 percent total suspended solids. The treated sludge was then sent through one of the BFPs. A block diagram with a schematic of the treatment processes and the location of the disintegration system for Phase I is shown in Figure 1-2.

Figure 1-2. Block Diagram for Phase I.



1.1.3. Phase II – Primary Digester Influent Sludge Disintegration

During the second phase, thickened sludge containing primary sludge, waste activated sludge and recuperative sludge was pumped through the disintegration system and returned to the primary digester feed. In place of the original planned seven-week period, this phase was performed for a period of one month. Thickened sludge was pumped at a rate of approximately 50 gpm, or 55 percent of the Primary Digester feed flow, at a thickness of 6.0 percent total suspended solids. A block diagram with a schematic of the treatment processes and the location of the disintegration system for Phase II is shown in Figure 1-3.

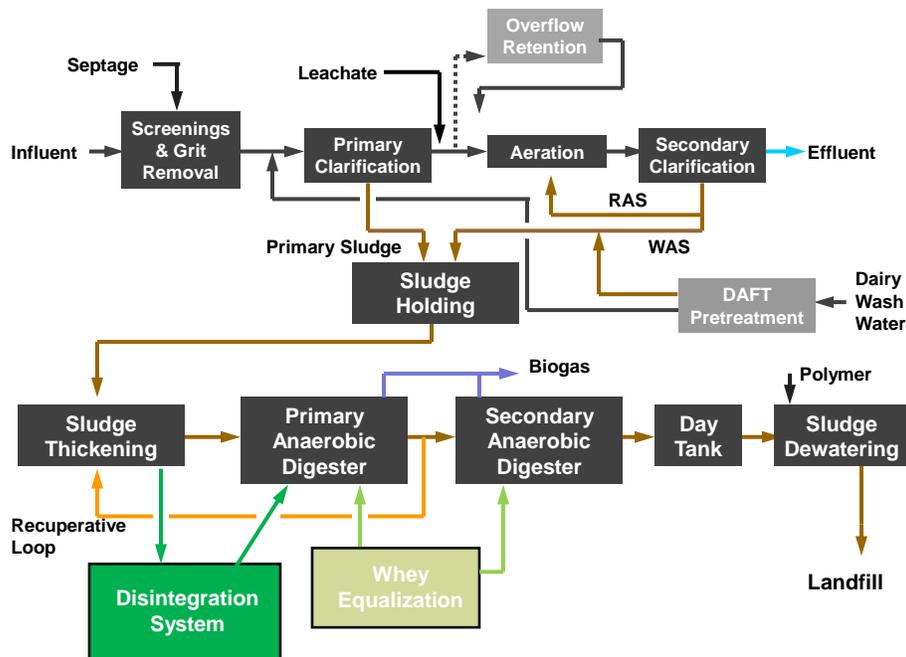


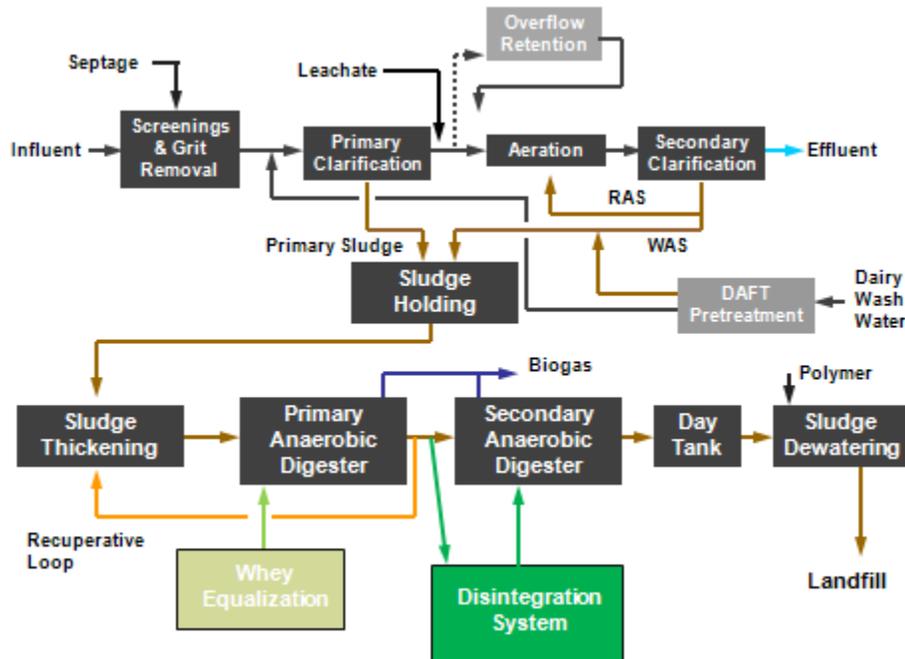
Figure 1-3. Block Diagram for Phase II.

1.1.4. Phase III – Secondary Digester Influent Sludge Disintegration

During this phase, all dairy whey was pumped to the primary digester. The Crown System was relocated to the digester building and primary digester effluent was pumped through the system at a rate of approximately 44 gpm, or 41 percent of the Secondary Digester feed flow, at a thickness of 2.8 percent total suspended solids. The disintegrated sludge was then returned to the secondary digester, which was operated at a temperature

of 98° F and mixed 20 hours per day. As previously mentioned, this phase was not originally planned, and was not included in the PMP. A block diagram with a schematic of the treatment processes and the location of the disintegration system for Phase III is shown in Figure 1-4.

Figure 1-4. Block Diagram for Phase III.



2. Pilot Results

The purpose of this pilot study is to determine the benefit of sludge disintegration at the WWTF. As previously mentioned, the pilot study was performed in three separate phases.

2.1. Baseline

In order to determine the impact of sludge disintegration on the performance of the anaerobic digesters, the 2011 operational year was evaluated and used as the baseline for comparison purposes. However, a few operational changes were made at the end of 2011 that continued during the pilot test period. Therefore, the baseline initially defined in the Performance Monitoring Plan was modified to reflect the operational changes. Table 2-1 compares the average operating parameters for the months of January through November 2011, to those for the months of November and December 2011.

**Table 2-1:
2011 Digester Monitoring and Performance Baseline Data**

Parameter	Unit	Annual Average	Nov-Dec Average
Primary Digester Alkalinity	mg/l	3,029	2,938
Primary Digester Volatile Acids	mg/l	124	123
Primary Digester pH	SU	7.0	6.9
Digester Biogas Flows	ft ³ /d	413,285	406,917
Biogas CO ₂ Content	%	42.0	41.0
Primary Digester Feed Flow	mgd	0.122	0.124
Primary Digester Feed Total Solids	lbs/d	56,467	57,665
Primary Digester Feed Total Solids	%	5.6	5.6
Primary Digester Feed Volatile Solids	%	79.8	80.1
Digested Sludge Flow	mgd	0.15*	0.14
Digested Sludge Total Solids	lbs/d	25,300	31,315
Digested Sludge Total Solids	%	2.7	2.8
Digested Sludge Volatile Solids	%	64.9	64.3
Dewatered Sludge Cake	wet tons	410	359
Dewatered Sludge Cake Total Solids	%	13.6	14.1
Organic Loading Rate	lbs VS/ft ³	0.22	0.23
Volatile Solids Reduction	%	48.1	55.2
Solids Residence Time	days	22.4	23.8
Biogas Production	ft ³ /lbs VS	21.8	15.8

*Note: the digested sludge flow was incorrectly reported in the PMP.

2.2. Phase I – Secondary Digester Effluent Sludge Disintegration

The goal of Phase I was to test if disintegration of sludge taken from the secondary digester would increase the subsequent dewaterability of the sludge (by liberating the water bound in the cellular materials).

If this were the case, an increase in the percent solids of the sludge cake should be observed; the goal was a sludge cake solids concentration greater than 16 percent. The results of Phase I testing are presented in Table 2-2.

**Table 2-2:
Phase I Test**

Parameter	Units	Baseline	Pilot Phase Goal	Phase I Average
Sludge Cake Solids	%	14.1	>16	13.8

Since disintegration is applied just prior to sludge dewatering, positive impacts of disintegration in this location should be measured immediately. However, the sludge treated in the disintegration unit just prior to dewatering had a comparable solids concentration to that of the average baseline. Therefore, Phase I testing did not indicate any benefits of sludge disintegration.

2.3. Phase II - Primary Digester Influent Sludge Disintegration

Similar to Phase I, the primary goal of Phase II was increasing the dewaterability of the sludge. During this phase, sludge disintegration was performed on thickened sludge. The intent was to rupture the cells prior to digestion, increasing the mass of volatile substrates in the digester and subsequently decreasing the mass of undigested material in sludge; material that is difficult to dewater. The primary goal was a sludge cake solids concentration greater than 16 percent. Additional benefits were also expected; an increase in the volatile solids reduction to 65 percent or greater, and an increase in the ratio of biogas produced per pound of volatile solids destroyed to 21.8 cf/lbVSS destroyed or greater.

Since the disintegration is applied upstream of the digesters, positive impacts of disintegration should be measured at the BFPs after a period corresponding to the sludge retention time (approximately 27 days), assuming complete mixing of the digesters. Results from this phase are presented in Table 2-3.

**Table 2-3:
Phase II Test**

Parameter	Units	Baseline	Pilot Phase Goal	Phase II Average
Sludge Cake Solids	%	14.1	>16	14.7
Volatile Solids Reduction	%	55.2	>65	45.8
Biogas Production	ft ³ / lbs VS	15.8	>21.8	20.3

Results from this phase also did not show any benefits of sludge disintegration for improving dewaterability of the sludge; the average percent solids of the sludge cake were similar to those of the baseline. And the volatile solids reduction actually decreased during this phase. However, biogas production did increase, to an average value of 20.3 cf/lbVSS destroyed.

One hypothesis for the decrease in volatile solids reduction is that, by disintegrating a combination of primary, waste activated, and recuperative sludges, the anaerobic bacteria present in the recuperative sludge are destroyed, which causes incomplete digestion. In other words, when recuperative sludge is disintegrated, the gains that should be made from increasing the SRT are lost due to the fact that the overall active biomass content is decreased.

2.4. Phase III - Secondary Digester Influent Sludge Disintegration

In Phase III, disintegration was performed on sludge from the primary digester prior to transfer to the secondary digester. The intent of this phase was to allow primary digestion to degrade the organics and reduce the volatile solids concentration of the sludge, and then perform disintegration on the remaining sludge so that additional substrates could be liberated and further digested. This concept should also allow the WWTF to take full advantage of the recuperative thickening process in the primary digester, which was thought to be an issue in Phase II.

The primary and secondary goals for this phase were similar to those set for Phase II - to increase the sludge cake solids concentration to greater than 16 percent, the volatile solids reduction to 65 percent or greater, and the ratio of biogas produced per pound of volatile solids destroyed to 21.8 cf/lbVSS or greater. Since disintegration is performed upstream of the secondary digester, results should be seen at the BFP after a period corresponding to the SRT of the secondary digester (approximately 13 days), assuming complete mixing of the digesters. Results from this phase are presented in Table 2-4.

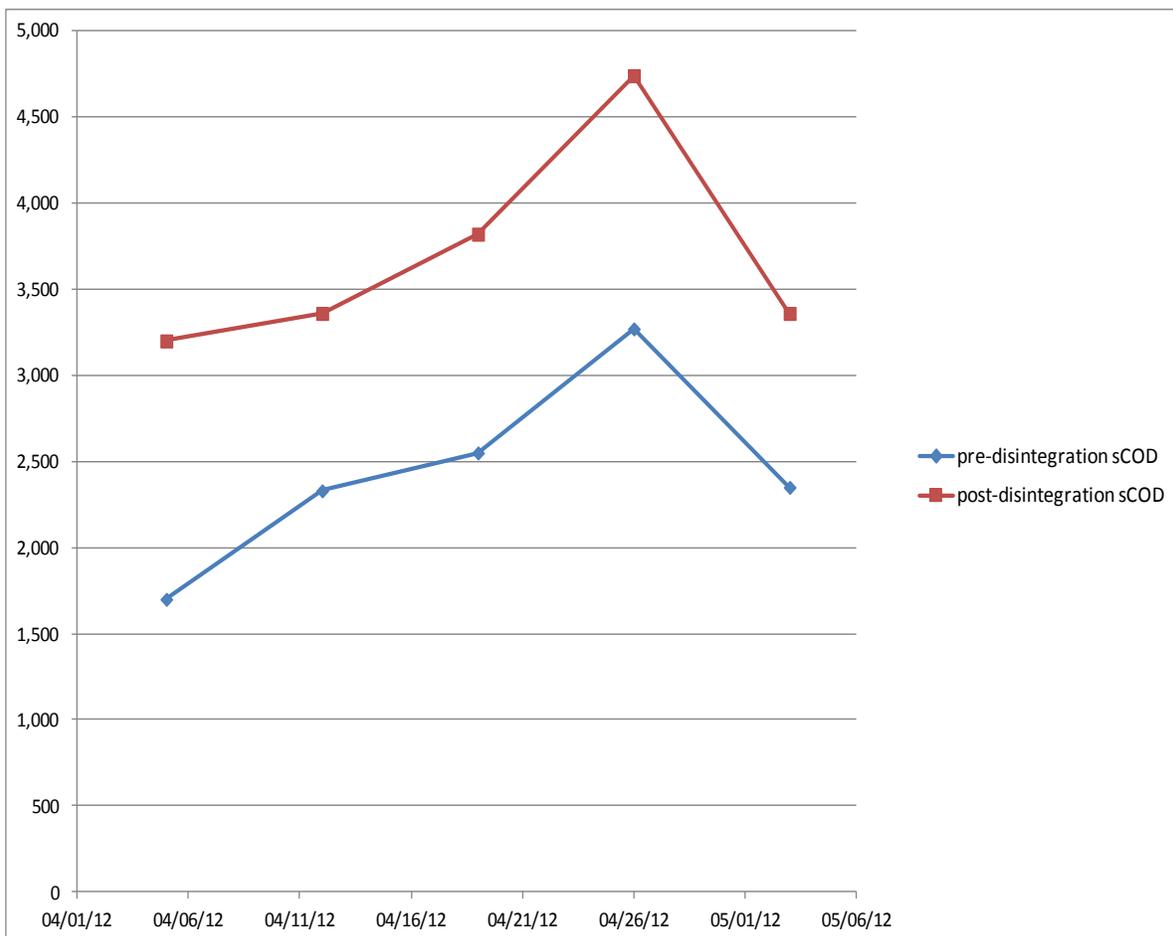
**Table 2-4:
Phase III Test**

Parameter	Units	Baseline	Pilot Phase Goal	Phase III Average
Sludge Cake Solids	%	14.1	>16	14.3
Volatile Solids Reduction	%	55.2	>65	61.1
Biogas Production	ft ³ / lbs VS	15.8	>21.8	19.8

While results from Phase III show an improvement in both volatile solids reduction and biogas production, the sludge cake solids concentration did not increase significantly, nor was the dewaterability goal achieved.

During Phase III, data were collected for several additional parameters: the soluble chemical oxygen demand (sCOD) of the influent to, and effluent from, the disintegration system; the total solids concentration from the secondary digester; and the volatile solids concentration from the secondary digester. [Typically, data for total and volatile solids samples were only collected from the thickened sludge feed to the primary digester, the primary digester effluent, and the sludge day tank prior to dewatering.] Data for these additional parameters are shown in Figure 2-1, 2-2, and 2-3, respectively.

Figure 2-1. Sludge Disintegration sCOD Concentration



As observed in Figure 2-1, the sCOD concentration in the post-disintegration sludge was much higher than that measured in the pre-disintegration sludge; indicating that sludge disintegration was indeed beneficial.

Figure 2-2. Phase III Total Solids Concentration

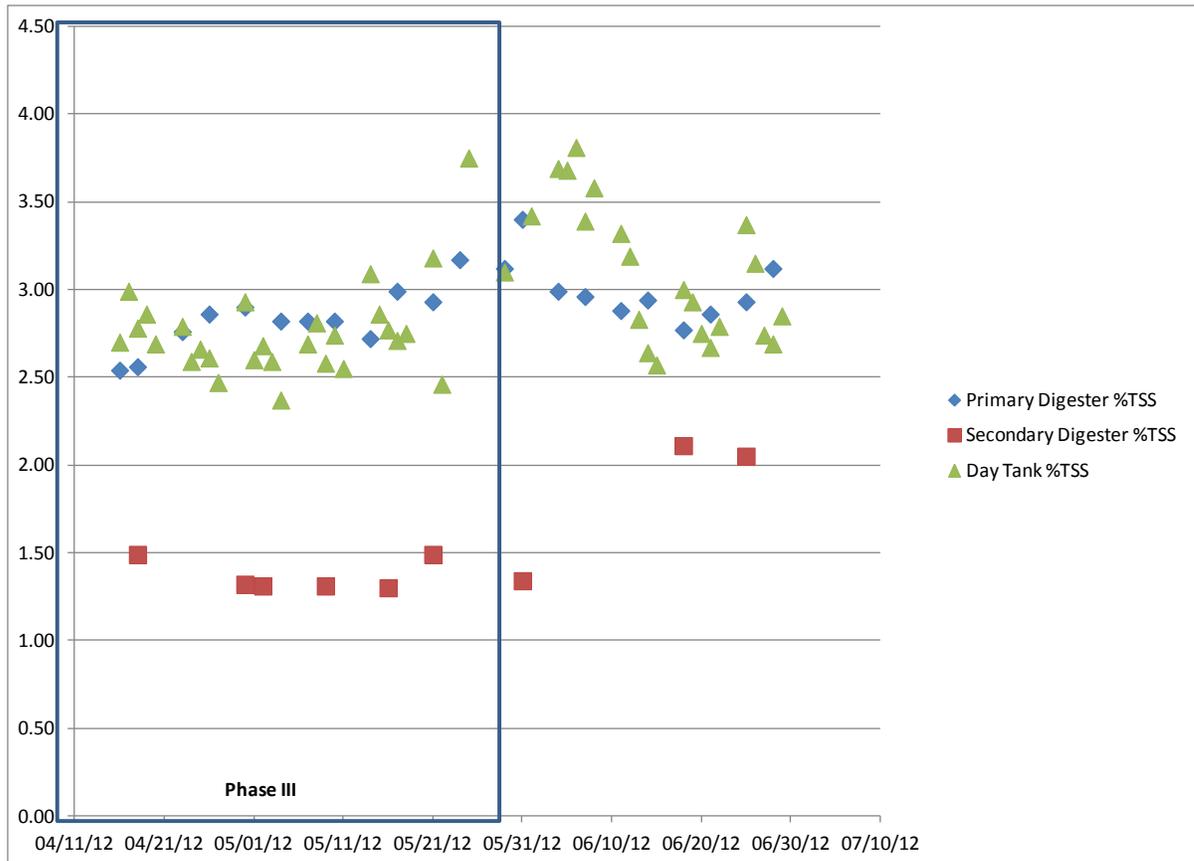
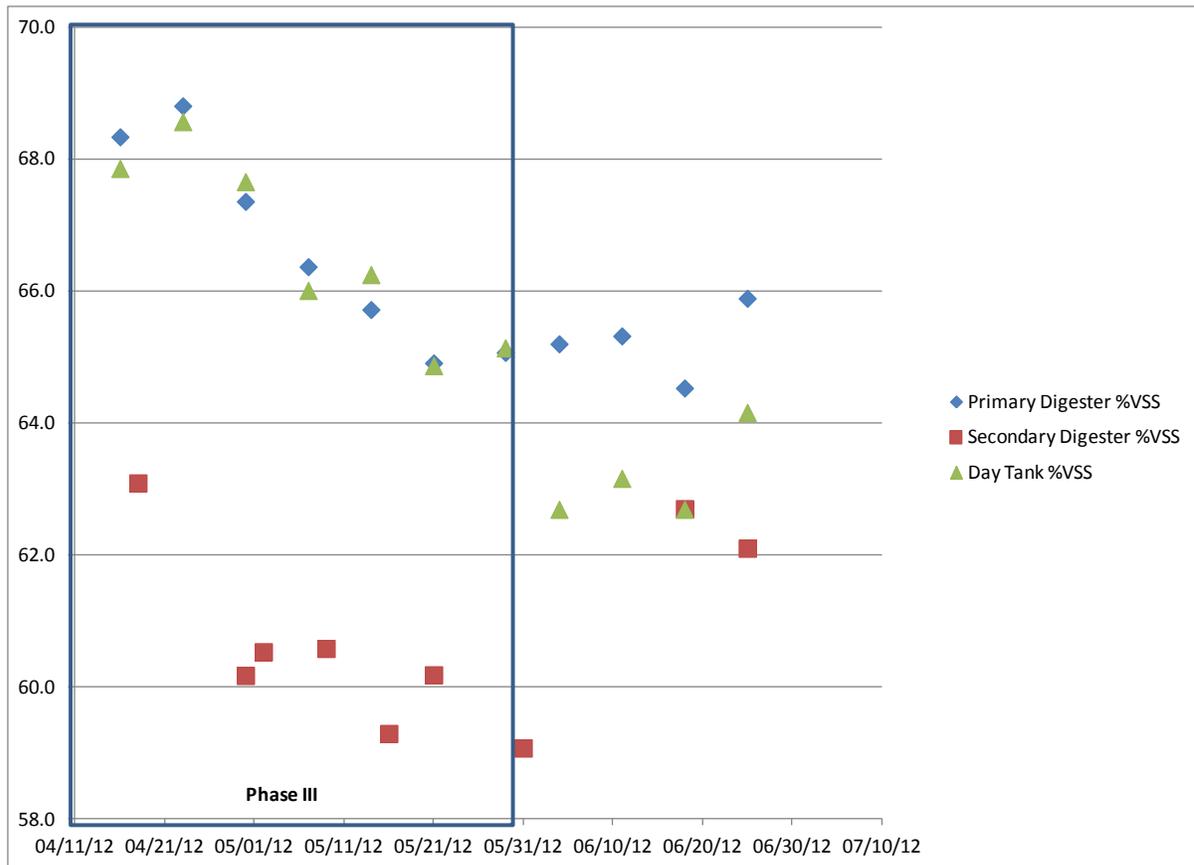


Figure 2-3. Phase III Volatile Solids Concentration



The following observations are associated with Figures 2-2 and 2-3:

- The total and volatile solids concentrations in the day tank closely track the total and volatile solids concentrations in the primary digester. However, the total and volatile solids concentrations in the secondary digester are lower than both. Since the secondary digester is located between the primary digester and the day tank, one would assume that the concentration in all three tanks would track similarly if the sludge disintegration system was not having an impact on the treatment process; or that lower solids concentrations would be observed in both the secondary digester and day tank due to the increased volatile solids reduction, increased biogas production, and reduced total sludge volume that results from sludge disintegration. [Note: in the original system, little to no digestion occurred in the secondary digester.]

- After the sludge disintegration pilot system was removed, the total and volatile solids of the secondary digester trended upward, tracking more closely to the concentrations observed in the primary digester and day tank.

One hypothesis for these observations is the possibility that the secondary digester is incompletely mixed and short-circuiting occurred, and/or there were physical configuration issues with the feed pipe. During Phase III testing, sludge was transferred from the primary digester via an 8 inch ductile iron pipe (DIP) and the disintegration unit was operated at approximately 44 gallons per minute (gpm). Similarly, the discharge from the pilot was conveyed through an 8 inch DIP that entered the secondary digester at a point approximately 13 feet up the side wall (or an elevation of 24.5 feet above the bottom cone). At 44 gpm, the sludge entered the secondary digester at a velocity of approximately 0.3 feet per second (fps), which is fairly slow. It is plausible that the sludge settled in the pipe; and this heavier, reconsolidated sludge fell to the bottom of the digester tank, while the soluble material remained in suspension. This denser sludge, if not near a mixer draft tube, could then have been withdrawn and directly transferred to the day tank, which seems plausible since the total and volatile solids concentrations in the day tank tracked that of the concentrations in the primary digester. And would therefore negate the observed impact of the sludge disintegration system on the secondary digester effluent.

2.5. Results Summary

Results from all three phases were charted, and the average parameters for each phase were compared to the 2011 baseline, as presented in the following figures.

Figure 2-4. Dewater Sludge Cake Solids Concentration

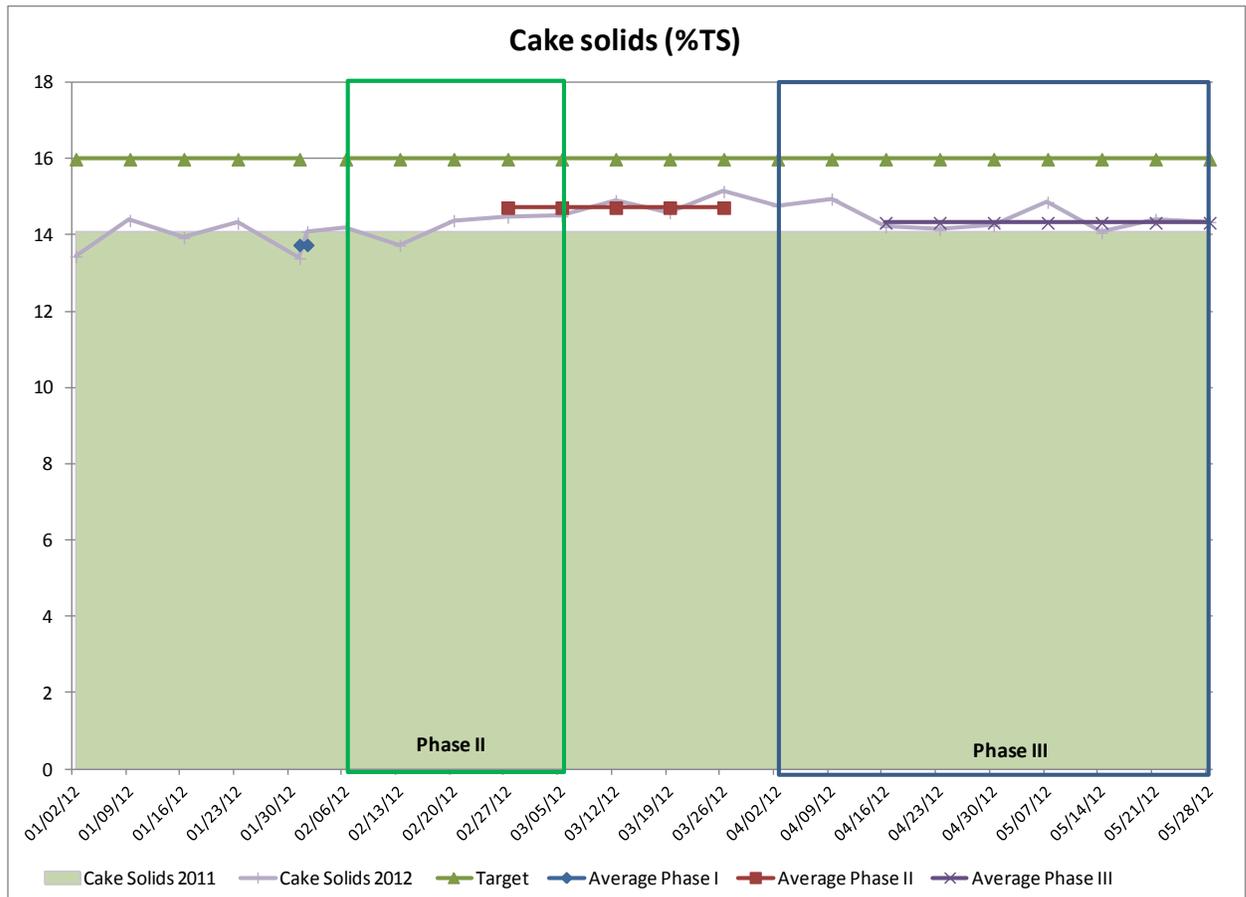
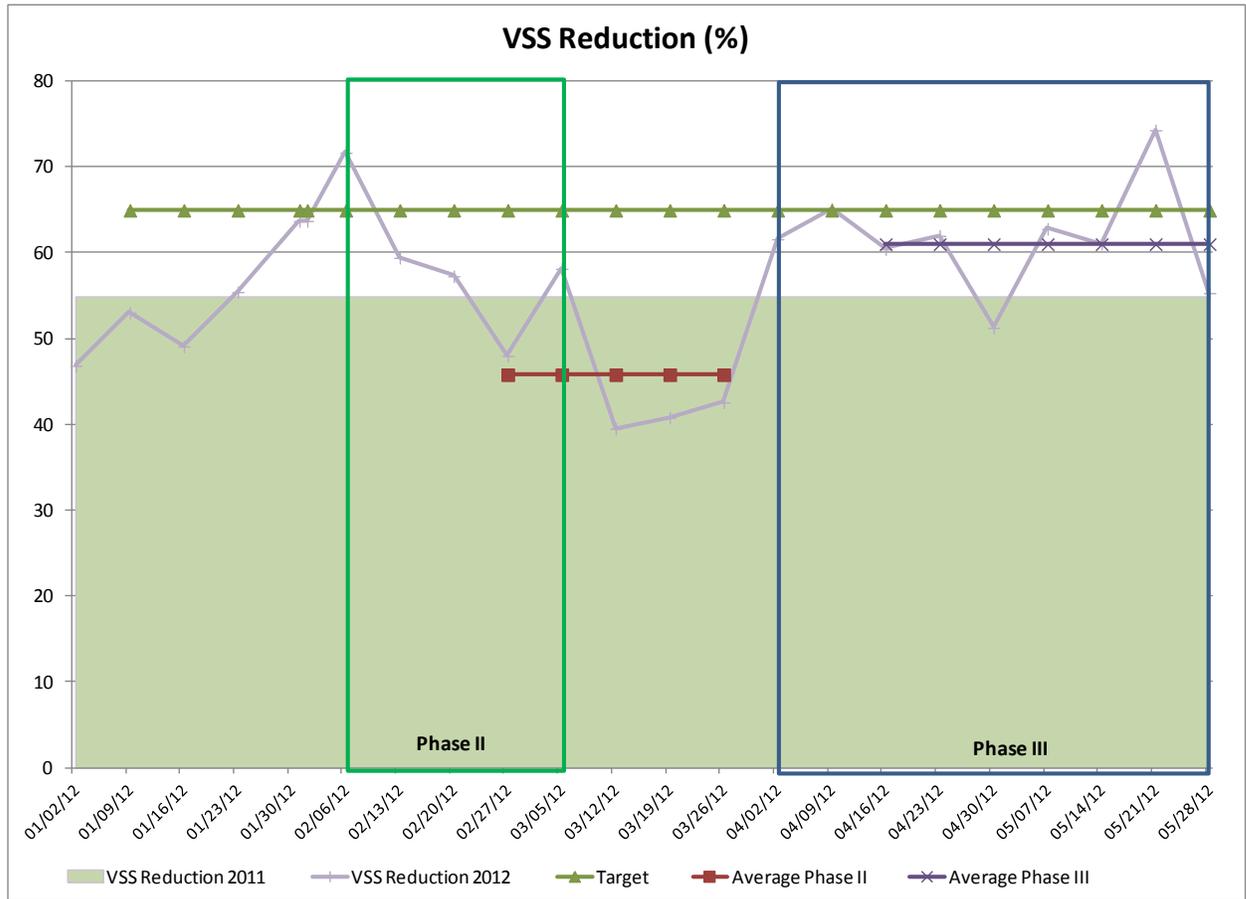


Figure 2-4 shows the cake solids percent as measured during 2012 compared to the 2011 baseline. Phases II and III are represented by a box around the pilot dates, and the average for each phase is delayed by a time corresponding to the SRT of either the primary or secondary digester, respectively. Figure 2-4 shows that a minor improvement in sludge dewaterability was observed; although the increase in percent solids did not meet the stated project goal of 16 percent or greater.

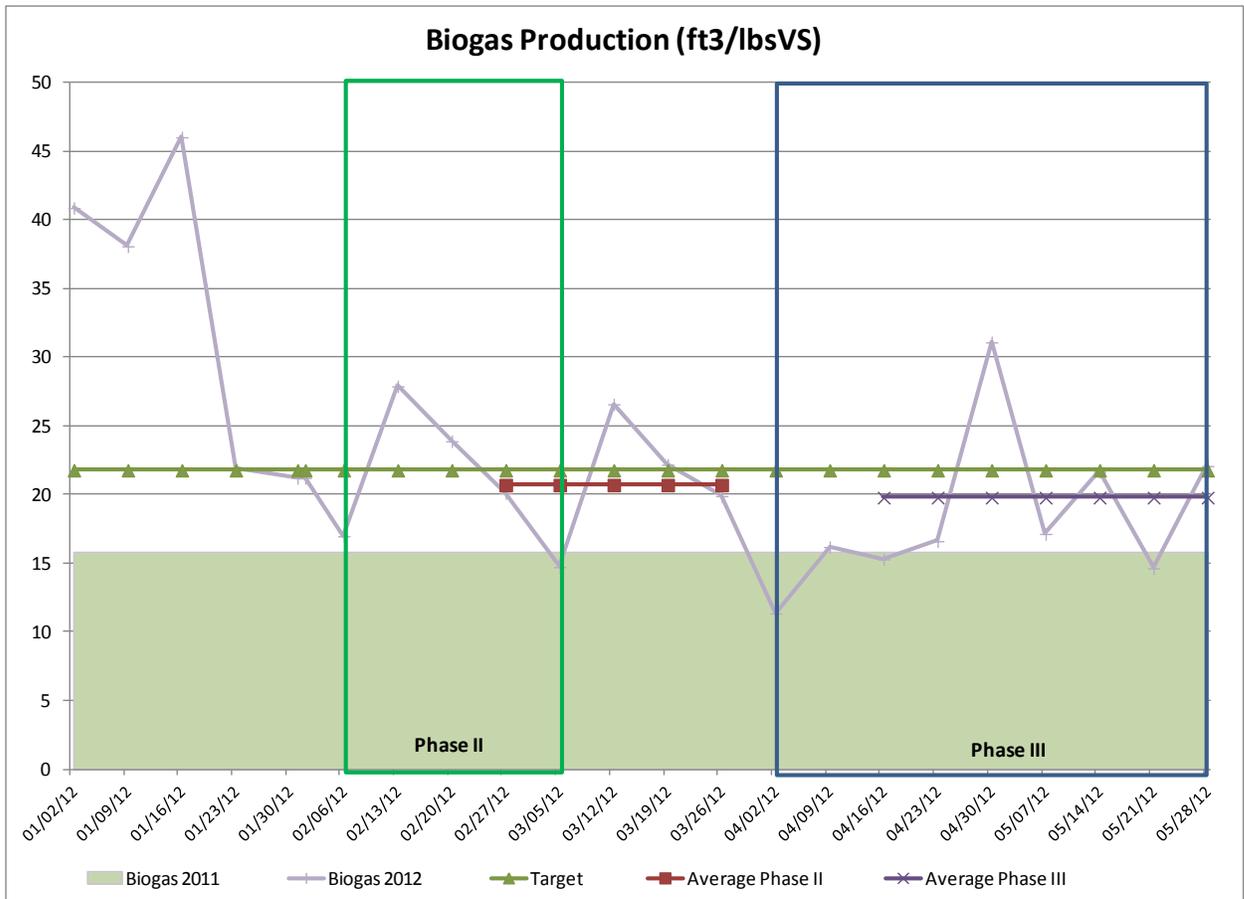
The volatile solids reduction and ratio of biogas produced per pound of volatile solids destroyed were also charted and are presented in Figures 2-5 and 2-6, respectively.

Figure 2-5. Volatile Solids Reduction.



As observed in Figure 2-5, the overall process efficiency was negatively impacted during Phase II when recuperative sludge was disintegrated with primary and waste activated sludges. While volatile solids reduction during Phase III showed improvement over that observed during Phase II, it did not meet the stated project goal of 65 percent or greater reduction.

Figure 2-6. Biogas Production.



As observed in Figure 2-6, the biogas generation rate increased during both Phases II and III, which seems to indicate that more sCOD substrate was released due to the sludge disintegration process and subsequently converted to biogas.

3. Pilot Evaluation and Conclusions

Some improvements to the overall processing of the WWTF's sludge were observed during pilot testing of the Crown System. Improved biogas production was observed during Phases II and III, and improved volatile solids reduction was observed during Phase III. These results indicate that the Crown System was contributing to cell wall rupture, and subsequent liberation of substrates from cellular material.

However, no improvement in sludge dewaterability and little improvement in the percent cake solids were observed. The failure to achieve improved sludge dewaterability may be explained, as mentioned previously, by incomplete mixing or short-circuiting in the secondary digester, due to the physical constraints of the transfer piping associated with the disintegration unit. If this were the case, it is unlikely that the disintegrated sludge was reaching the day tank and dewatering process. This hypothesis is supported by the fact that the concentration of the total and volatile solids in the secondary digester increased after the pilot unit was taken off line, matching the concentrations observed in the primary digester and day tank; the volatile solids concentration in the secondary digester was approximately 60 percent during Phase III testing, and currently averages approximately 65 percent. If short-circuiting could be resolved, perhaps improved dewaterability would also be observed.