BioElectric Treatment of Waste Activated Sludge

In June 2013 ElectroCell Technologies conducted a pilot test to evaluate the impact of BioElectric cell lysis technology on Thickened Waste Activated Sludge (TWAS) at the Derry Township Municipal Authority (DTMA) in Hershey, PA.

The objective of this pilot was to determine if BioElectric treatment would break down TWAS into soluble and more bioavailable forms as a precursor to enhanced anaerobic digestion.

ElectroCell's BioElectric technology uses precisely managed, low voltage electrical pulses to break down liquid wastes. It has been used for several years to destroy pathogens, stratify nutrients, settle solids and reduce odors in livestock manure and biosolids. Only low levels of electricity (less than 3 watts per gallon) are used. There are no chemicals or additives involved.

Figure 1. ElectroCell mobile BioElectric systems are self-powered, operate unattended, process up to 100 gallons per minute and are towed by a pickup truck.

Background

DTMA is a state-of-the-art, 5 MGD wastewater treatment facility utilizing two-stage mesophilic anaerobic digestion. In addition to TWAS and primary solids, DTMA co-digests sludge from a neighboring candy factory and Fats, Oils and Grease (FOG). In 2012, DTMA's anaerobic digestion process destroyed 52.8% of Total Suspended Solids (TSS).

Figure 2. Derry Township Municipal Authority's Clearwater Road WWTP, Hershey, PA.

Even in high performing anaerobic digesters such as DTMA's, a substantial portion of solid inputs resist digestion. Anaerobic digestion is a hydrolysis-limited process. The key to more complete digestion is making sludge inputs, especially Waste Activated Sludge (WAS), more bioavailable by lysing cells and improving solubility.

Several technologies have been explored in the last 30 years to pre-treat digester inputs by breaking down organic solids into simpler organic forms and increasing dissolved and suspended organic material available to the digester microbial population. With successful pre-treatment, anaerobic digestion will convert more solids to gas, thus increasing renewable energy production and reducing the volume of residual biosolids.

Pre-treatment techniques developed over the past 30 years include various combinations of heat, pressure, mechanical shearing, chemical lysing and/or high-voltage electrical pulses. Many of these techniques have been able to demonstrate sludge degradation and improved digestion in limited applications, but none have proven to be the simple, reliable, energy efficient solution that would attract wide-scale acceptance.

The Pilot Test and Sampling Plan

The primary objective of this trial was to determine if ElectroCell's BioElectric Treatment would lyse cells and break down TWAS in measureable ways known to increase bioavailability and "digestibility". An important secondary objective was to determine the extent of Fecal Coliform destruction to assess whether BioElectric pre-treatment could eventually contribute to the production of Class A biosolids in mesophilic digesters.

Figure 3. The ElectroCell team setting up a pilot test at DTMA.

ElectroCell pumped TWAS directly from a sump and deposited control and treated material into six 250-gallon totes for monitoring. Two totes were filled at 60 Gallons Per Minute (GPM) without BioElectric Treatment as a control. Two totes were filled and BioElectrically treated at the rate of 60 GPM (Trial 1) and the final two totes were filled and BioElectrically treated at 42 GPM (Trial 2).

Treatment speeds were reduced from the BioElectric design speed of 100 GPM due to the unique characteristics of DTMA's TWAS. It was expected that the high solids (4.0 – 4.3% solids) and low conductivity (< 0.5 mS/cm) material might require longer retention time in the BioElectric reactor tubes for effective treatment.

Date	Activity
June 19th, 2013 (Day 1)	AM setup, PM treatment & tear down
	Initial meter readings & lab samples
June 21st, 2013 (Day 3)	Start three-mixers one hour before meter readings and lab samples taken from totes
June 26th, 2013 (Day 7)	Final meter readings and lab samples

Table 1. Timeline of Pilot Treatment Activities

A Hanna Instruments multiparameter meter was used on-site to measure the following parameters at every sampling period:

- Temperature
- pH
- Total Dissolved Solids (TDS)

Samples were evaluated in DTMA's on-site lab for the following tests:

- Total Solids (TS)
- Total Suspended Solids (TSS)
- Volatile Solids (VS)
- Soluble Chemical Oxygen Demand (SCOD)

Samples were also sent to Agri Analysis for Fecal Coliform tests and to Benchmark Analytics for semi-Soluble Chemical Oxygen Demand (sSCOD) tests.

Once filled, the six totes were moved indoors and monitored for seven days. Day 1 samples were taken within an hour of filling. Each pair of totes included one tote with a mixer to simulate digester mixing and one tote left unmixed. The plan was to mix three of the totes for the entire seven days, but mixers were not activated until one hour before the Day 3 sampling event. The first hour of mixing was not deemed to be effective so samples from all six totes on Day 3 are considered "unmixed". Mixers remained in operation from Day 3 through the final sampling event on Day 7.

Figure 4. Four of the six totes used in the pilot. Three of the totes were mixed using modified, low speed drywall mixers configured to keep material moving without inducing aeration.

Results Summary

BioElectrically treated material demonstrated clear indications of floc disintegration and cell lysis although the results varied by treatment speed and mixing conditions.

Mixing and the associated increase in biological activity had a significant effect on both treated and untreated material. By Day 7, the mixed control tote had become noticeably thicker and gelatinous. This thickening is evident in the significant changes in TDS, TSS and TS data below. Mixing impacted the Trial 1 and Trial 2 material differently.

Trial 1 (60 GPM) material exhibited subtle but consistent evidence of floc disintegration and cell lysis in the unmixed tote, but those changes were not enough to overcome the impact of mixing. The mixed Trial 1 material exhibited no significant differences from the mixed control material.

Trial 2 (42 GPM) demonstrated the most significant changes in solids profile and solubility. The key measures of solubility, TDS and SCOD, were significantly higher in the Trial 2 material and the Fecal Coliform and TSS were significantly reduced. The changes are evident in the unmixed material, with every test indicating significant changes in the TWAS. The mixing process amplified the differences between control and Trial 2 material. For example, Trial 2 unmixed material produced 72% higher TDS than the control. Under mixed conditions, Trial 2 TDS was more than 100 times higher than the control. The visual differences in the material were consistent with the data. The Trial 2 mixed tote was the only mixed tote that maintained it's pre-mixed viscosity.

Trial 2 results were produced with electricity inputs of 1.5 watts per gallon treated, including pumping. This is about 50% of the typical BioElectric energy input. The BioElectric process was modified to treat the unique characteristics of TWAS. Further refinements to increase the energy inputs to approximately 3 watts per gallon in TWAS are underway. These refinements are expected to improve the results and/or allow an increase in the treatment rate.

The data from each test is summarized below. Mixed and unmixed data are shown separately due to the significant differences mixing produced. A complete table of results is included in Exhibit A, at the end of this report.

Soluble Chemical Oxygen Demand

Figure 5 (below) tracks the changes in SCOD. SCOD in the Trial 2 mixed tote increased by 1,815% over seven days. SCOD also increased in the mixed control tote, but Trial 2 mixed tote ended up with 281% higher SCOD than in the mixed control.

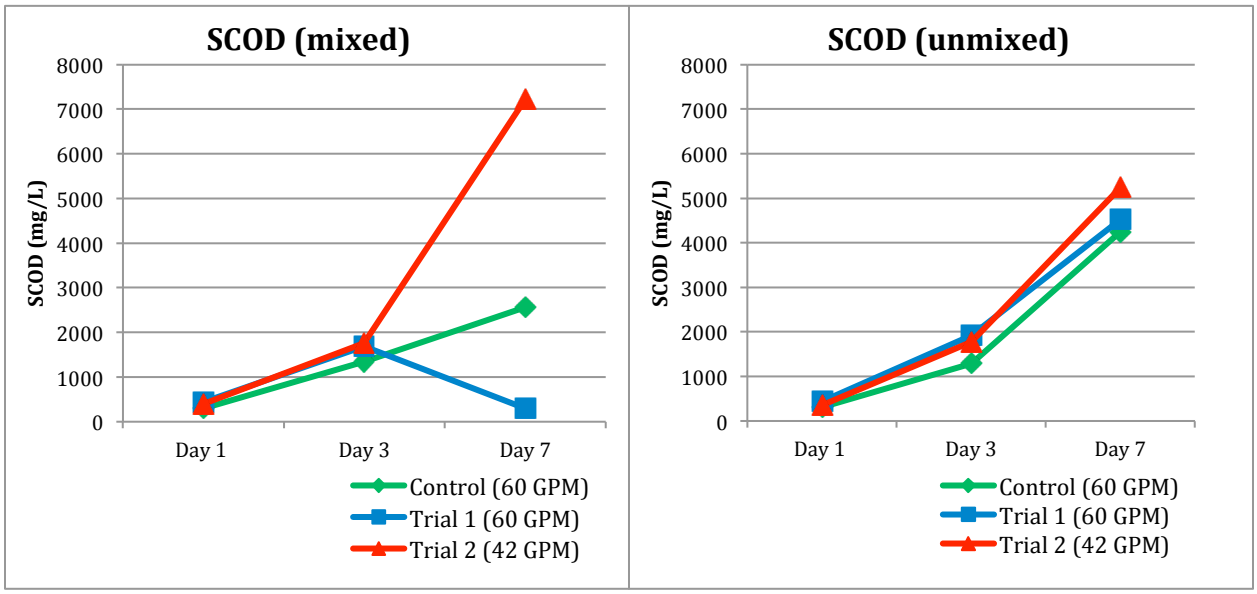

Figure 5. Soluble Chemical Oxygen Demand

Semi-Soluble Chemical Oxygen Demand

sSCOD measures the breakdown of organic solids into semi-soluble or colloidal forms, which are more bioavailable to anaerobic digester microbes.

Figure 6 (below) tracks sSCOD results. The data suggests that BioElectric treatment increased sSCOD, especially in Trial 2, but the changes are relatively subtle and will warrant further testing.

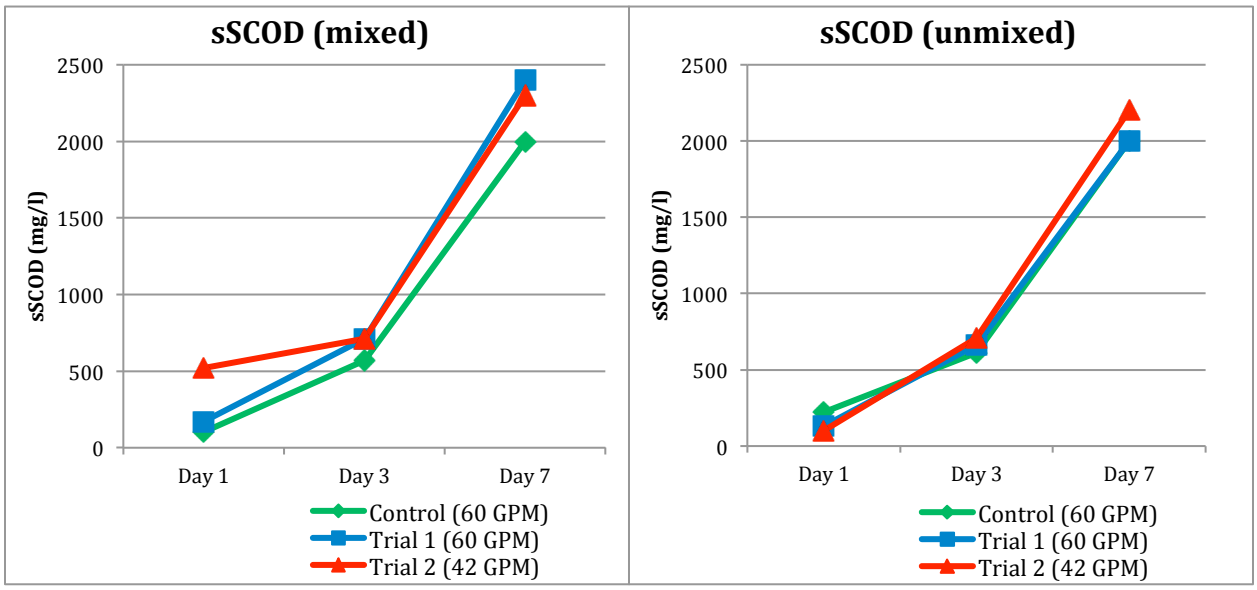

Figure 6. Semi-Soluble Chemical Oxygen Demand

Fecal Coliform

Figure 7 (below) tracks changes in Fecal Coliform. In previous BioElectric trials where aerobically and anaerobically digested biosolids were treated, Fecal Coliform were rendered undetectable.

The Fecal Coliform destruction in this seven day trial was not as complete, but it was significant. Trial 2 material exhibited the most complete Fecal Coliform destruction in both mixed and unmixed totes. At the Day 7 sampling event, Trial 2 mixed material achieved Fecal Coliform levels of 1,600 Colonies / 100 mL.

The Trial 1 results tracked closely with the control in both tests with the exception of the Day 1 mixed sample which appears to be an outlier at 490,000 Colonies / 100 mL.

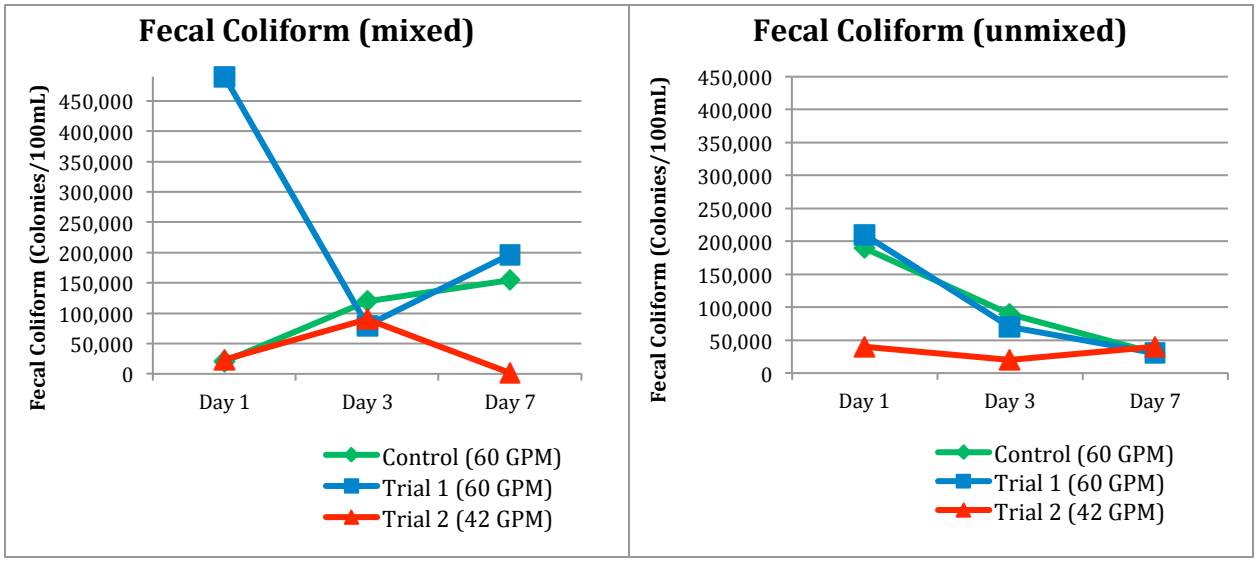

Figure 7. Fecal Coliform

Total Dissolved Solids

Figure 8 (below) tracks the changes in Total Dissolved Solids (TDS). All three unmixed totes demonstrated a linear increase in TDS over seven days with both Trial 1 and Trial 2 exhibiting roughly 70% higher TDS than the control.

Again, mixing altered the behavior of the material. Both mixed control and Trial 1 totes solidified significantly, exhibiting TDS less then 10 ppm by Day 7.

TDS in the Trial 2 mixed tote continued to increase, but at a slower rate after mixing began. By Day 7, the Trial 2 mixed material exhibited TDS more than 100 times higher than the control. This difference was visually apparent with Trial 2 mixed material clearly less vicious than the other two mixed totes.

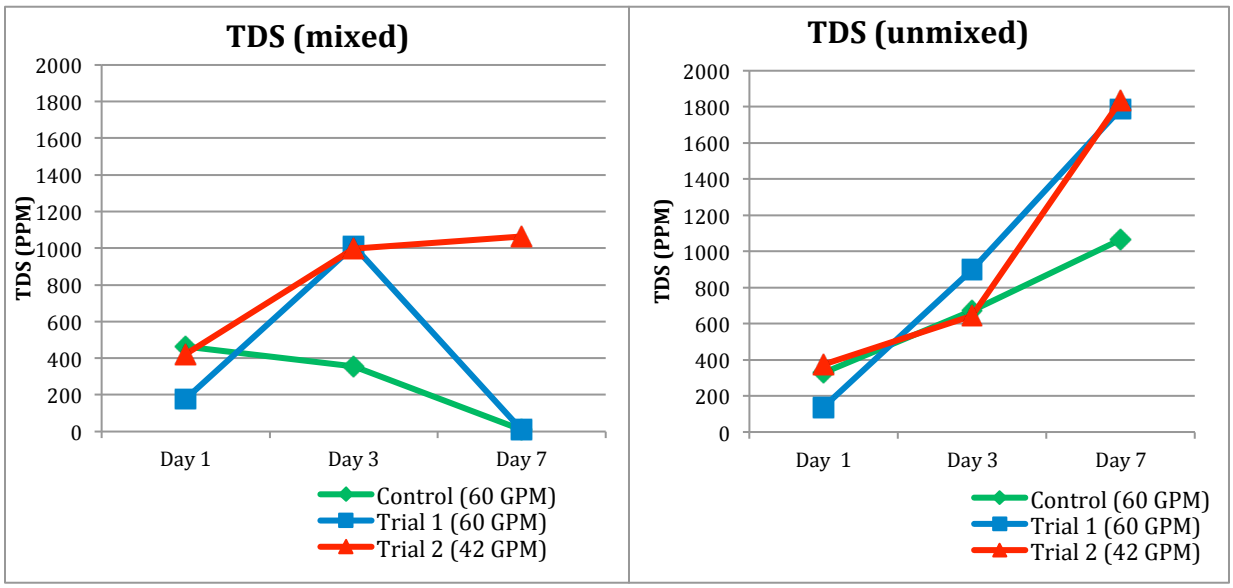

Figure 8. Total Dissolved Solids

Total Suspended Solids

Figure 9 (below) tracks the changes in Total Suspended Solids (TSS). The unmixed material exhibited relatively stable TSS with Trial 1 and Trial 2 exhibiting slightly higher levels.

Trial 2 mixed material exhibited the most dramatic change with 59% lower TSS than the mixed control material by Day 7.

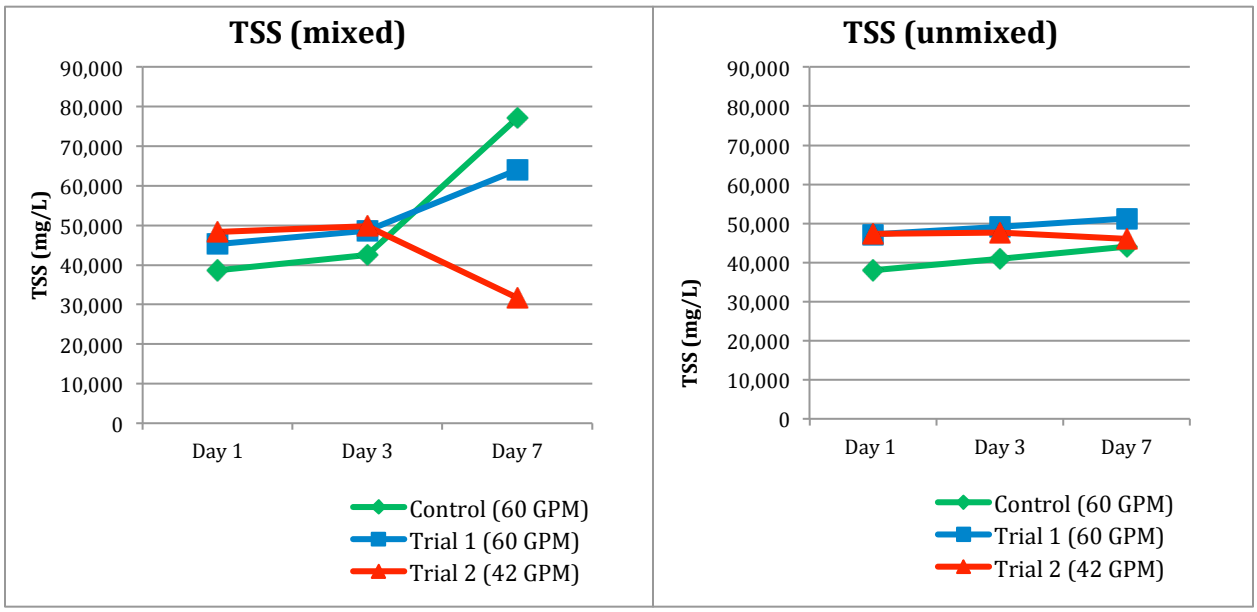

Figure 9. Total Suspended Solids

Total Solids (TS)

Figure 10 (below) tracks the changes in Total Solids (TS). The TS results paralleled the TSS results above with relatively stable values in the unmixed material and significant differences in Trial 2 mixed material. By Day 7, Trial 2 mixed material demonstrated 41% less TS than the mixed control.

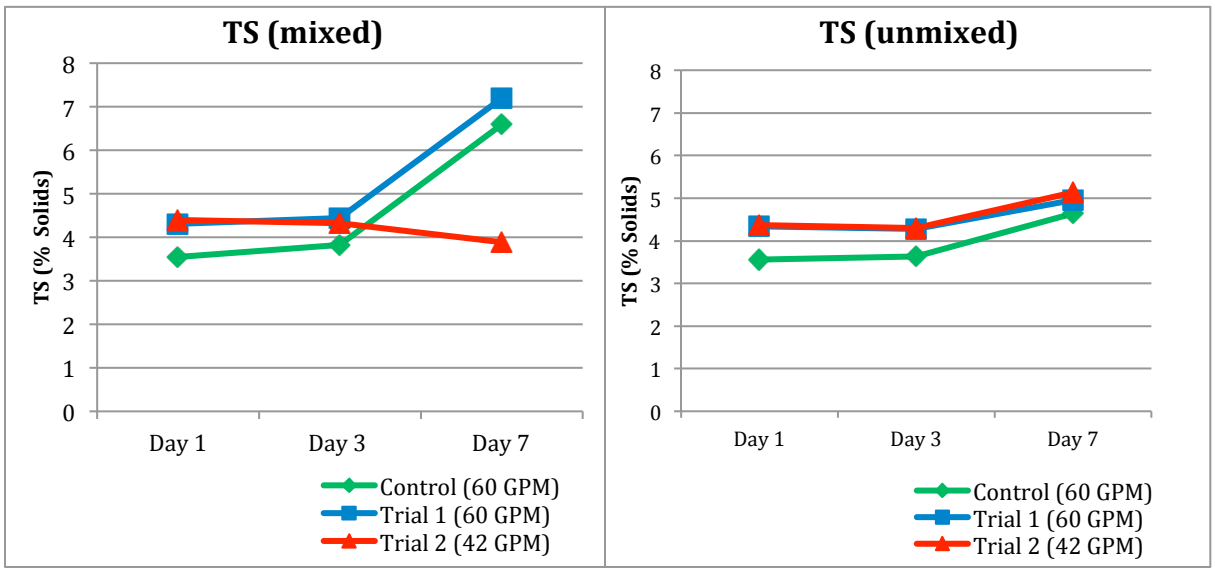

Figure 10. Total Solids.

Percent Volatile Solids to Total Solids

Figure 11 (below) tracks the changes in Volatile Solids as a percentage of Total Solids (VS). VS in both the mixed and unmixed Trial 2 totes began about 8% lower than the other totes.

Where control material exhibited a steady drop in VS, both Trial 1 and Trial 2 exhibited higher VS by Day 7. The changes in Trial 2 mixed material were, once again, the most dramatic. Despite starting 8% lower than mixed the mixed control material, Trial 2 mixed ended up 10.4 % higher by Day 7.

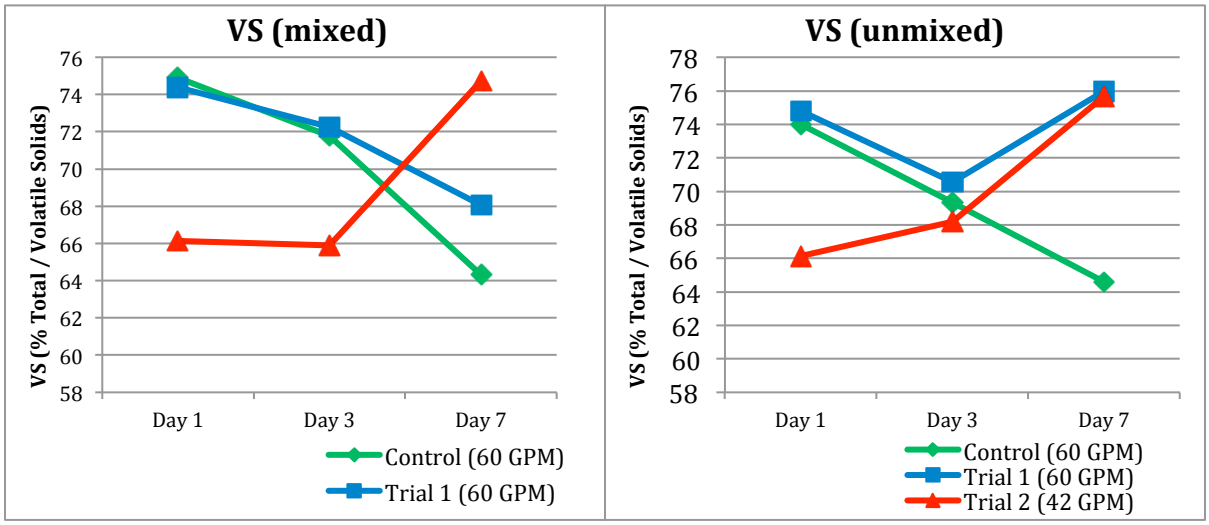

Figure 11. Volatile Solids Percent of Total Solids

pH

The pH of all six totes dropped over the course of seven days, but treated material dropped consistently lower with Trial 2 material dropping below 6.0 in both the mixed and unmixed totes. This may be evidence of accelerated biological activity and the formation of acids.

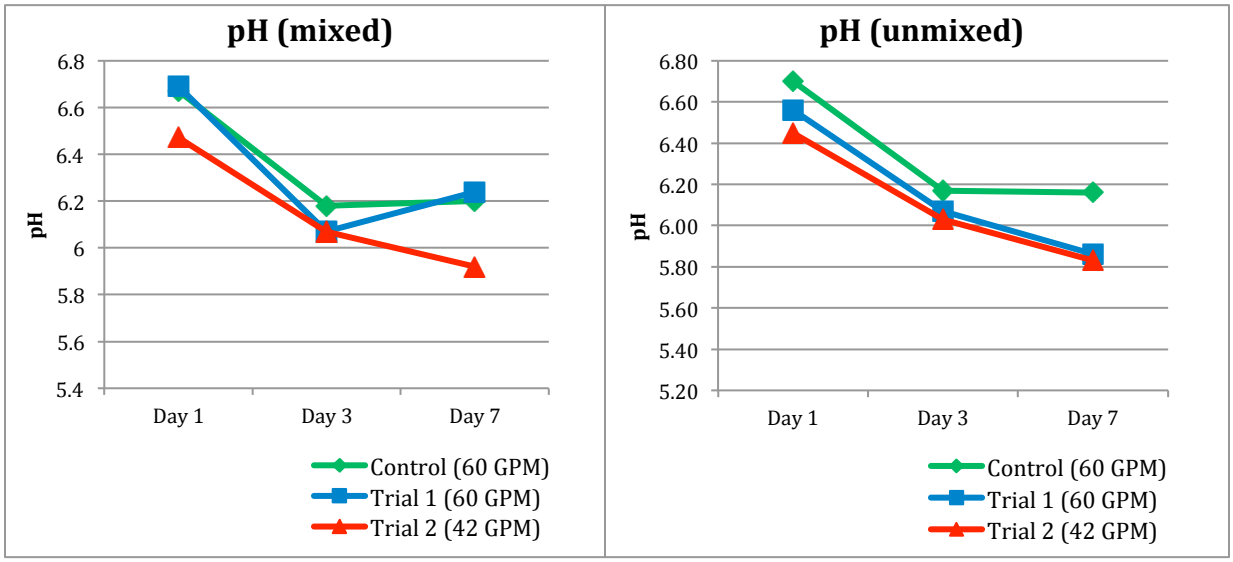

Figure 12. pH

Temperature

Figure 13 (below) tracks material temperatures. There were no significant differences in temperature between the six test totes. ElectroCell's low-energy BioElectric process does not produce meaningful sludge heating.

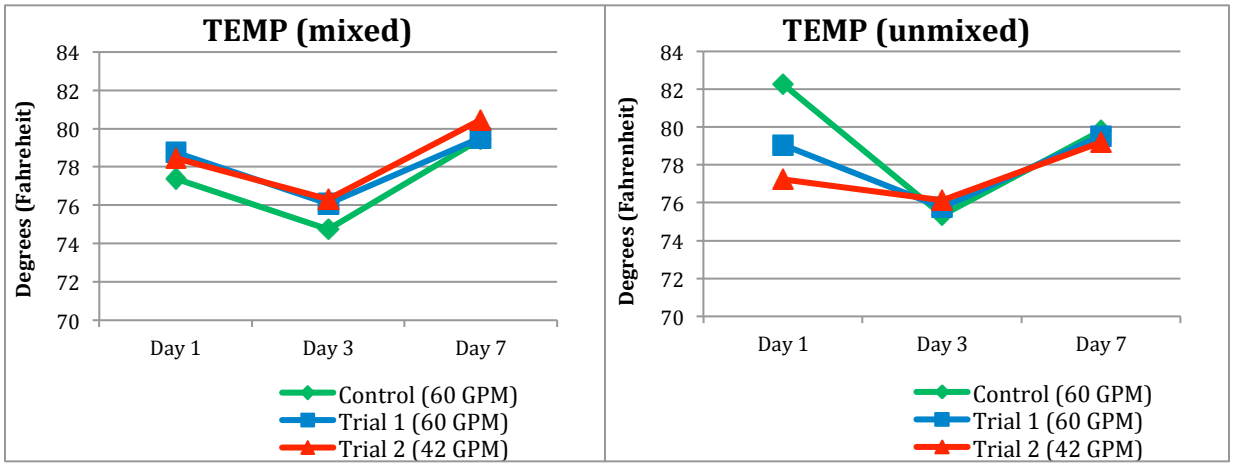

Figure 13. Temperature

Conclusion

Trial 1 (60 GPM) demonstrated some indications of cell lysis, but the limited results were overwhelmed by the mixing process. At the trial energy input level of 1.5 watts per gallon, the flow rate of 60 GPM does not appear to provide sufficient treatment time.

Trial 2 (42 GPM) demonstrated clear and consistent evidence of cell lysis, particularly in mixed material, which most closely resembles the conditions found in an anaerobic digester. Table 2 (below) summarizes the differences between Trial 2 mixed and the mixed control material at the conclusion of the monitoring period.

	Control (Day 7)	Trial 2 (Day 7)	% Difference
Soluble Chemical Oxygen Demand (mg/L)	2,564	7,225	281.79%
Semi-Soluble Chemical Oxygen Demand (mg/L)	2,000	2,300	15%
Total Dissolved Solids (ppm)	10	1,065	10,550%
Volatile Solids as % of Total Solids	64.3%	74.7%	10.4%
Total Suspended Solids (mg/L)	77,050	31,680	-58.88%
Fecal Coliform (Colonies/100 ml)	154,000	1,600	-98.96%
pH	6.2	5.92	-4.52%
Temperature (Fahrenheit)	79.45	80.46	1.27%

Table 2. Day 7 comparison of Trial 2 and Control mixed totes

With energy consumption of only 1.5 watts per gallon treated and a flow rate of 42 GPM, BioElectric treatment appears to be a promising alternative to more energy intensive cell lysis technologies.

Additional testing is planned to evaluate higher energy input levels and different flow rates on a variety of digester inputs including TWAS, primary solids, industrial sludge, FOG and/or blended inputs. These tests will also focus on the destruction of all Class A marker pathogens including Fecal Coliform, Salmonella, Helminth Ova and Enteric Virus.

Appendix A - Complete Trial Data

		TDS			TDS		
	DAF				Mixed	Mixed	Mixed
Date	Sump	Control (60 GPM)	Trial 1 (60 GPM)	Trial 2 (42 GPM)	Control (60 GPM)	Trial 1 (60 GPM)	Trial 2 (42 GPM)
Day 1	319	327	138	372	462	176	421
Day 3		670	898	643	356	1,010	998
Day 7		1,065	1,787	1,832	10	8	1,065

		TSS			TSS		
	DAF				Mixed	Mixed	Mixed
Date	Sump	Control (60 GPM)	Trial 1 (60 GPM)	Trial 2 (42 GPM)	Control (60 GPM)	Trial 1 (60 GPM)	Trial 2 (42 GPM)
Day 1		38,020	47,200	47,380	38,640	45,240	48,300
Day 3		41,000	49,200	47,700	42,550	48,650	49,800
Day 7		44,120	51,240	46,040	77,050	64,050	31,680

		TS			TS		
	DAF				Mixed	Mixed	Mixed
Date	Sump	Control (60 GPM)	Trial 1 (60 GPM)	Trial 2 (42 GPM)	Control (60 GPM)	Trial 1 (60 GPM)	Trial 2 (42 GPM)
Day 1		3.56	4.34	4.37	3.55	4.31	4.40
Day 3		3.64	4.28	4.30	3.82	4.44	4.33
Day 7		4.64	4.95	5.14	6.60	7.19	3.89

		Volatile Solids			Volatile Solids		
	DAF				Mixed	Mixed	Mixed
Date	Sump	Control (60 GPM)	Trial 1 (60 GPM)	Trial 2 (42 GPM)	Control (60 GPM)	Trial 1 (60 GPM)	Trial 2 (42 GPM)
Day 1		74.01	74.79	66.14	74.89	74.37	66.14
Day 3		69.35	70.55	68.18	71.77	72.24	65.89
Day 7		64.58	75.98	75.68	64.31	68.05	74.71

Date	DAF Sump	SCOD Control (60 GPM)	SCOD Trial 1 (60 GPM)	SCOD Trial 2 (42 GPM)	SCOD Mixed Control (60 GPM)	SCOD Mixed Trial 1 (60 GPM)	SCOD Mixed Trial 2 (42 GPM)
Day 1		305	442	356	297	439	398
Day 3		1,284	1,918	1,772	1,344	1,686	1,766
Day 7		4,245	4,520	5,245	2,564	294	7,225

Date	DAF Sump	sSCOD Control (60 GPM)	sSCOD Trial 1 (60 GPM)	sSCOD Trial 2 (42 GPM)	sSCOD Mixed Control (60 GPM)	sSCOD Mixed Trial 1 (60 GPM)	sSCOD Mixed Trial 2 (42 GPM)
Day 1		220	130	100	100	170	520
Day 3		610	660	710	570	710	710
Day 7		2,000	2,000	2,200	2,000	2,400	2,300

Date	DAF Sump	Fecal Coliform Control (60 GPM)	Fecal Coliform Trial 1 (60 GPM)	Fecal Coliform Trial 2 (42 GPM)	Fecal Coliform Mixed Control (60 GPM)	Fecal Coliform Mixed Trial 1 (60 GPM)	Fecal Coliform Mixed Trial 2 (42 GPM)
Day 1		190,000	210,000	40,000	20,000	490,000	24,000
Day 3		90,000	70,000	20,000	120,000	80,000	90,000
Day 7		30,000	30,000	40,000	154,000	197,000	1,600

Date	DAF Sump	pH Control (60 GPM)	pH Trial 1 (60 GPM)	pH Trial 2 (42 GPM)	pH Mixed Control (60 GPM)	pH Mixed Trial 1 (60 GPM)	pH Mixed Trial 2 (42 GPM)
Day 1	6.69	6.70	6.56	6.45	6.67	6.69	6.47
Day 3		6.17	6.07	6.03	6.18	6.07	6.07
Day 7		6.16	5.86	5.83	6.20	6.24	5.92

		TEMP			TEMP		
	DAF				Mixed	Mixed	Mixed
Date	Sump	Control (60 GPM)	Trial 1 (60 GPM)	Trial 2 (42 GPM)	Control (60 GPM)	Trial 1 (60 GPM)	Trial 2 (42 GPM)
Day 1	69.37	82.28	79.06	77.23	77.37	78.75	78.44
Day 3		75.33	75.73	76.13	74.74	76.07	76.31
Day 7		79.80	79.54	79.19	79.45	79.53	80.46