Optimizing Two-Stage Anaerobic Digestion via Recycle From an Aerobic Digester

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Objectives

Anaerobic digestion is often used in larger wastewater treatment plants (WWTPs), as aerobic digestion can become too energy-intensive at such scales. Research has started taking a harder look into the benefits of postaerobic digestion (PAD) following anaerobic digestion.

Having a long history of researching and improving aerobic digestion methods, Thermal Process Systems (TPS) sought to apply its existing technologies and knowledge of aerobic digestion to a two-stage anaerobic digestion system. One of the primary methods of failure for anaerobic digesters is becoming overloaded with volatile fatty acids (VFAs). This occurs as a result of the acidogens making VFAs at a faster rate than the methanogens can convert the VFAs to methane. Two-stage anaerobic digestion was used to separate out the more-rapid stages of hydrolysis and VFA formation from the much slower step of methane production.

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Optimizing and stabilizing the anaerobic digesters significantly reduces the oxygen demand in a postaerobic digester, therefore reducing the energy requirements. The primary goal of coupling aerobic digestion to anaerobic digestion with a recycle stream was to improve the stability of the anaerobic digester, therefore increasing the volatile solids reduction (VSR), improving biogas production and quality, reducing the overall hydraulic retention time (HRT) for the digestion process, and improving the dewatering characteristics. The effects of varying the recycle rate from the aerobic digester to the fermenting digester were also observed.

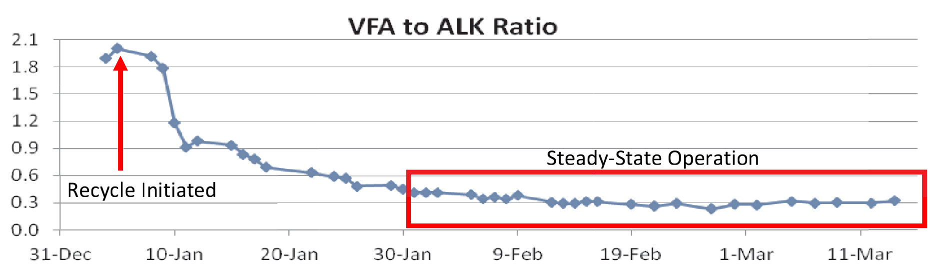

Figure 1. Methanogen reactor volatile fatty acids-to-alkalinity ratio

POLYMER DOSAGE						OBSERVED FLOCCULATION			
Polymer Addition [mL]	Neat [lb./ dry ton]	Active [lb./ dry ton]				EM 975	EM 1375	EM 1475	EM 1575
		EM 975	EM 1375	EM 1475	EM 1575				
7.0	30.3	13.6	12.4	13.6	12.1	PF	PF	MF	MF+
9.0	39.0	17.5	16.0	17.5	15.6	PF	MF	**FF**	FF
11.0	47.6	21.4	19.5	21.4	19.0	PF	FF		**FF**
13.0	56.3	25.3	23.1	25.3	22.5	PF	FF		
15.0	64.9	29.2	26.6	29.2	26.0	PF	**FF**		
17.0	73.6	33.1	30.2	33.1	29.4	MF			
19.0	82.3	37.0	33.7	37.0	32.9	MF			

where **FF** is the best conditioning

Sample	Pan Weight [g]	Pan & Sample Weight, Wet [g]	Pan & Sample Weight, Dry [g]	Sample Weight, Wet [g]	Sample Weight, Dry [g]	% Total Solids
1375 Centrate	0.720	10.964	0.733	10.244	0.013	0.13%
1375 Cake	0.725	1.263	0.886	0.538	0.161	29.93%
1475 Centrate	0.722	10.447	0.736	9.725	0.014	0.14%
1475 Cake	0.731	1.219	0.888	0.488	0.157	32.17%
1575 Centrate	0.738	9.933	0.748	9.195	0.010	0.11%
1575 Cake	0.731	1.154	0.849	0.423	0.118	27.90%

Figure 2. Dewatering results

Scope

The pilot-scale study was carried out with a blend of primary sludge (PS) and waste activated sludge (WAS) collected from the Crown Point (Ind.) WWTP. The facility utilizes standard anaerobic digestion and feeds a blend of PS that is gravity thickened, and WAS that is thickened via a gravity belt thickener (GBT). The pilot system followed the feeding schedule of the Crown Point facility (typically Monday through Friday) over the course of two years, which meant dealing with the same variations in the feed material as a result of seasonal changes, equipment being taken down for maintenance, facility construction, etc.

Liquid samples taken daily from each digester were tested for total solids (TS) and volatile solids (VS) content. The liquid samples were tested in a Hach DR3900 Spectrophotomer for multiple parameters. Draeger gas detector tubes were used to test the carbon dioxide, ammonia, and hydrogen sulfide in the off-gas of each digester. Gas chromatography (GC) testing was occasionally used to confirm the results of the gas detector tubes. Dewatering chemical dosing rates were preliminarily determined via laboratory jar testing. Mechanical dewatering results representative of centrifuge dewatering were obtained by sending samples to Centrisys Centrifuge Systems in Kenosha, Wis.

Methods

Operation of the pilot unit commenced without utilizing a recycle from the aerobic digester to establish a baseline. During the initial phase of the pilot demonstration, the operational liquid levels of each tank were set so that the fermentation tank, methanogen reactor, and aerobic digester operated at two-, 15-, and eight-day HRTs, respectively. Each phase of the pilot demonstration lasted for three sludge ages of steady-state operation.

After the first phase of operating in a plug-flow fashion, the recycle was initiated at 60 percent of the daily feed amount. The recycle rate was later increased to 100, 150, and 200 percent of the daily feed amount to observe the ability of the system to reduce the struvite precipitation potential in the anaerobic digester by decreasing the ammonia.

Results

The plug-flow operation of the pilot unit resulted in the methanogen reactor becoming overloaded with VFAs. This was accompanied by a decrease in the VSR, biogas production, and methane concentration in the biogas. Initiating the recycle rapidly lowered the VFA to alkalinity ratio (VFA/ALK) in the reactor, bringing it to literature values that designate a healthy anaerobic digester (Figure 1). The VFA/ALK was maintained at proper values without spikes in the VFA concentration or foaming events in the methanogen reactor for the remainder of the pilot demonstration. The methanogen reactor consistently achieved 55 to 60 percent VSR with the recycle in effect. Dewatering results from Centrisys showed a significant improvement to the dewatering characteristics of the digested biosolids (Figure 2). No coagulant, and only 18 active pounds of polymer per dry ton of biosolids, were required to achieve 32 percent TS in the dewatered cake.

The elimination of a requirement for standard metal salt coagulants reduced the amount of phosphorus in the biosolids cake, bringing the nitrogen-to-phosphorus ratio in the cake to the range that agronomic studies suggest makes up a healthy soil. Increasing the recycle through the system effectively allowed the aerobic digester to remove a larger mass of ammonia from the methanogen reactor daily (Figure 3). The decreasing ammonia was accompanied by a controlled pH adjustment in

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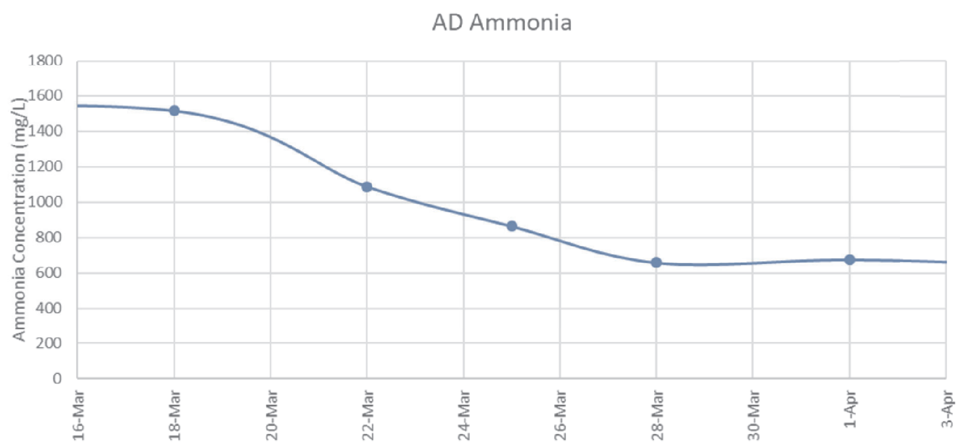

Figure 3. Methanogen reactor ammonia after increasing recycle rate

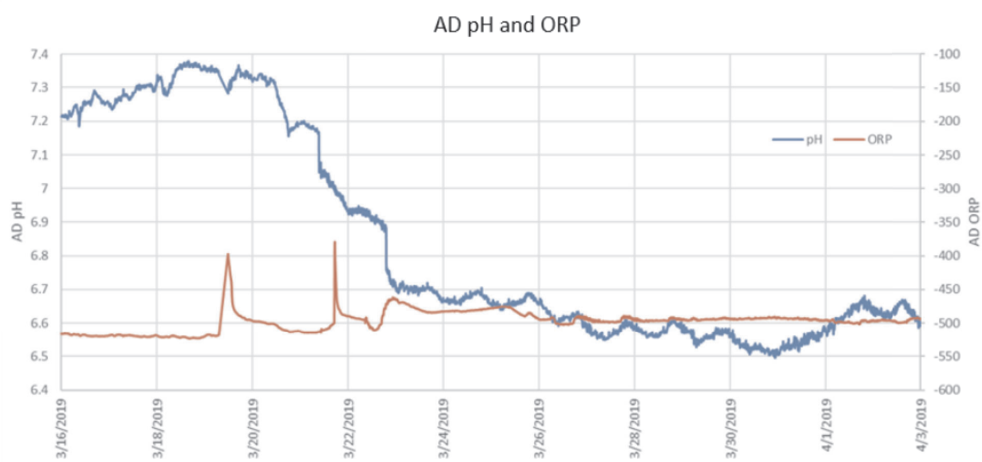

Figure 4. Methanogen reactor pH after increasing recycle rate

Sample ID: 19080101
Description: Waste Water AD2
Received: 8/1/2019
Sample No.: 16307-001

	Result	Units	Technique
Atmospherics			
Hydrogen (H_2)	< 0.1	Mol %	GC-TCD
Oxygen (O_2)	3.59	Mol %	GC-TCD
Nitrogen (N_2)	16.57	Mol %	GC-TCD
Methane (CH_4)	62.03	Mol %	GC-TCD
Carbon monoxide (CO)	< 0.1	Mol %	GC-TCD
Carbon dioxide (CO_2)	17.81	Mol %	GC-TCD
Sulfur, S			
Hydrogen sulfide (H_2S)	5.6	ppb v	GC-ICP-MS
Carbonyl sulfide (COS)	< 5.0	ppb v	GC-ICP-MS
Isopropyl mercaptan	14	ppb v	GC-ICP-MS
Thiophene	43	ppb v	GC-ICP-MS

Figure 5. Gas chromatography biogas results

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reactor. The methanogen reactor maintained less than 550 mg/L of ammonia and a pH of 6.7 throughout the steady-state portion of this phase of the pilot, levels that theoretically eliminate the production of struvite (Figure 4).

These effects were not accompanied by a decrease in the VSR or biogas production. An unexpected result that was observed was that the hydrogen sulfide (H_2S) in the biogas became nondetectable with the Draeger tubes. The GC results confirmed this observation with a reported H_2S concentration of 5.6 parts per bil (ppb), while also confirming the methane concentration at 62 percent in the biogas (Figure 5). Further research revealed previously published discussions of the ability of nitrates to inhibit the activity of sulfate-reducing bacteria (SRBs) that produce H_2S by offering a more thermodynamically favorable electron receptor. The nitrates supplied by the recycle from the aerobic digester inhibited the SRBs, while promoting a sulfur-oxidizing, nitrate-reducing bacteria. This allowed the system to decouple the nitrification and denitrification processes by shifting denitrification to the fermentation tank.

Conclusion

This pilot demonstration showed the capabilities of coupling two-stage anaerobic digestion to a conditioning aerobic digester that recycled material through the system. The recycle supplied by the aerobic digester offset variations in the feed material, improving the stability of the anaerobic digestion process. Maintaining high VSR increases the total amount of methane produced through anaerobic digestion. High VSR combines with the reduction of dewatering chemical requirements and higher cake solids to offer substantial cost savings for facilities.

The ability of the recycle to reduce the struvite potential in the methanogen reactor reduces maintenance concerns that often accompany anaerobic digestion. This is linked to the elimination of H_2S in the biogas, which removes the need for more expensive forms of H_2S treatment and continuous maintenance of boilers and combined heat and power (CHP) units. The capabilities of this system offer cost savings and solutions for problems that many anaerobic digestion facilities face.