Anaerobic Digester Monitoring Helps Avoid Process Upsets and Maximize Biogas Production

Introduction to Anaerobic Digestion

Anaerobic digestion is a commonly used technology in municipal and industrial solids stabilization processes. Stabilization is a process that reduces the treatment process' sludge pathogen content, rendering the product safe for beneficial use or disposal. Anaerobic digestion is used in various private industries and is utilized by roughly 10% of all municipal water resource recovery facilities (WRRF).

Anaerobic digestion differs from other stabilization processes in its potential to recover energy via captured biogas. Biogas is produced as a byproduct of the digestion process and can be used in boiler systems for heat production, engines/turbines connected to generators for energy generation or even further treated to produce other fuels, such as natural gas. This ability to capture stored energy present in our waste streams makes anaerobic digestion an attractive technology as water resource recovery facilities continue to work towards resource recovery as an integrated aspect to regulatory compliance.

Anaerobic digesters are fed by sludge captured or generated by upstream processes in the WRRF liquid treatment stream as well as captured fats, oils, and greases (FOG) or food/industrial wastes. While there are many specific configurations for anaerobic digesters (mesophilic, thermophilic, etc.) the objective remains the same: create an environment that promotes the controlled and stable decomposition of organic matter via naturally occurring biological pathways. This is accomplished in four simultaneous stages: Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis.

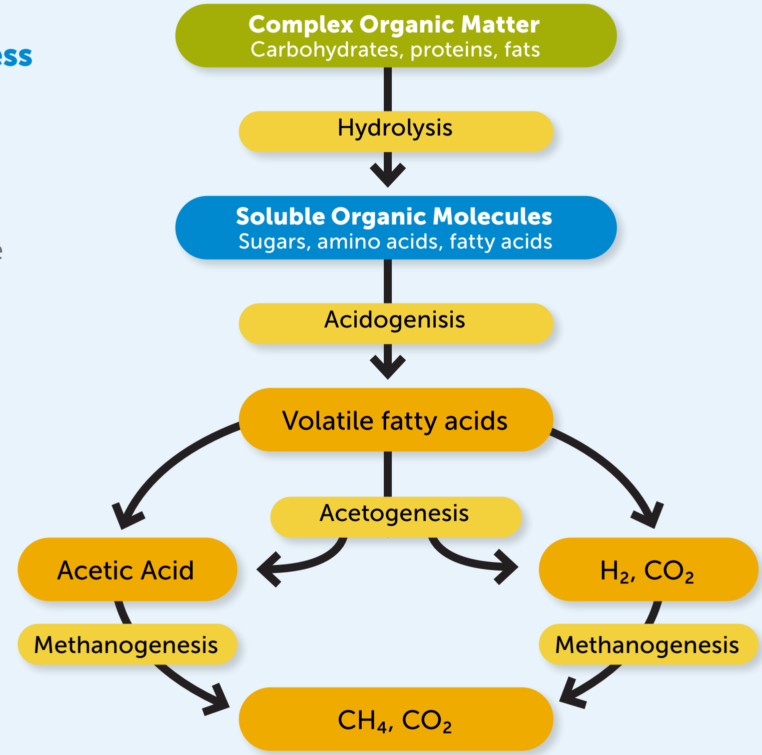
Methane forming bacteria are sensitive to many process conditions, including temperature, pH, and the presence of various toxins. Optimal performance occurs within a pH range of 6.8-7.2. If pH levels drop in the digester, the methane-formers can be inhibited, halting the digestion process and biogas production altogether.

Medina County Sanitary Engineers – Kenneth J Hotz WRF

Medina County Sanitary Engineers supports the public utilities serving the city of Medina, Brunswick, and several other townships. The county maintains three water reclamation facilities, including the newly renamed Kenneth J Hotz WRF, formerly known as the Liverpool Wastewater Treatment Plant. At this site, the county funded upgrades to increase renewable energy capture from their anaerobic digester system.

Overview of the Anaerobic Digestion Process

1. **Hydrolysis** – organic matter/cells are broken down into a soluble form
2. **Acidogenesis** – Soluble organic molecules are converted into volatile fatty acids (VFA) by acid producing bacteria
3. **Acetogenesis** – further breakdown of VFA's, primarily into acetic acid (steps 2 and 3 can collectively be referred to as fermentation)
4. **Methanogenesis** – VFA and hydrogen are converted into methane (biogas) and carbon dioxide by methane producing bacteria



This is generally referred to as digester souring – an odor producing, time consuming, and expensive failure of the system which can often cost tens of thousands of dollars to recover from.

Digester stability is greatly increased when high levels of alkalinity are present. Alkalinity is defined as a solutions ability to resist changes in pH in the presence of acids/bases. In anaerobic digesters, alkalinity is consumed during the production of VFA in stage 2 referenced above. Fortunately, bicarbonate alkalinity is produced as the methane-formers convert VFA into methane, as referenced in stage 3 above. Digester operators can maintain a healthy balance between VFA and alkalinity based on carefully monitored operational control of feed rates, mixing, and heating.

While anaerobic digestion processes are well understood, digester upsets or inefficient energy recovery issues are still challenges commonly faced by operators.

Anaerobic digestion efficiency can be substantially improved by implementing pretreatment technologies that lyse the cells being fed into the digester. Cell lysing improves the efficiency, energy capture, environmental sustainability, and solids reduction in the digestion process. One such pretreatment technology is thermal hydrolysis process (THP). This process uses extreme pressure and heat to achieve these results. While pretreatment of anaerobic sludge can vastly improve the digestion process, the system should also be carefully monitored to prevent digester over-feeding.

Anaerobic Digester Monitoring

Typical anaerobic digester monitoring consists of periodic grab samples (ideally daily) for laboratory analysis of pH, alkalinity, and VFA. While this may be enough for highly consistent applications, most anaerobic digesters are subject to a high degree of variability in their operational conditions. In such cases, additional monitoring or increased sample frequency may be desired to avoid upsets or simply maximize performance and energy recovery.

Digester stability and optimal energy recovery can be consistently and safely achieved with the help of continuous monitoring of some key leading indicators of the digester health. Based on the digester's sensitivity to changes in temperature and pH, operators may be tempted to simply monitor digester pH and temperature to avoid upsets. However, this approach is insufficient due to the nature of the failure. Essentially, once the pH is changing, digester souring may already be inevitable due to the exhaustion of the available alkalinity. In such events, methanogenesis has likely already been inhibited. Direct real-time monitoring of the ratio of VFA and alkalinity produced in the digesters (VFA:ALK) is a more valuable tool in tracking the overall health of the anaerobic digestion process. In addition to the VFA:ALK ratio, the specific bicarbonate alkalinity levels can help provide insight into the digester stability as it relates to the quality of the feedstock (for example, higher levels of bicarbonate alkalinity have been associated with feedstocks higher in protein content). This ratio provides a much earlier insight into the health of the methane-forming bacteria and helps operators maintain optimal performance and energy recovery.

Case Study: Medina County Sanitary Engineers – Liverpool WWTP

In the early 2010's, Phil Cummings (superintendent) and Dawn Taylor (assistant superintendent) at the Kenneth W. Hotz Water Reclamation Facility (formerly known as the Liverpool Wastewater Treatment plant) in Medina County, Ohio, faced the challenge of figuring out how to improve their solids handling process. Their incumbent technology consisted of an aging Wet Air Oxidation process that was energy intensive, requiring significant gas and electricity to operate. In conjunction with their consultants, the county decided to move in a direction that would be more environmentally sustainable and energy positive – anaerobic digestion with thermal hydrolysis.

Transitioning from Wastewater Treatment to Resource Recovery

The city decided on anaerobic digesters with Thermal Hydrolysis Pretreatment to maximize their energy recovery via optimal biogas production and capture. To ensure optimal digester feed rates and to generally monitor digester health continuously, the county began looking for online monitoring technologies to supplement the standard laboratory procedures used in monitoring the health of anaerobic digesters (grab samples for VFA, alkalinity, and pH). After a thorough market search, the plant decided to purchase the Hach EZ7250 Analyzer to monitor digester VFA, Bicarbonate, Alkalinity, and pH in real time. This technology was particularly useful when starting up the THP system to ensure digester feed rates did not result in excessive VFA production, which could lead to inhibiting pH levels for the methane-forming bacteria, while also ensuring maximum biogas production.

VFA:ALK Ratios	Background	Measure
0.8	Methane production ceases	Stop feed, add alkalinity
0.6 - 0.7	Digester stability is critical	Reduce or stop feed, add alkalinity
0.4 - 0.5	Anerobic conditions are upset	Reduce feed rate, adjust operating conditions, consider adding alkalinity
0.3 - 0.4	Biogas production is high	Consider reducing feed rate or adjust operating conditions
0.2 - 0.3	Biogas production is moderate	Continue to closely monitor digester conditions
< 0.2	Biogas production is low/conservative	Potential to slowly increase feed for higher gas production

Suggested actions for the assessment of VFA:ALK ratios (Adapted from MOP 16 "Anaerobic Sludge Digestion" 1987).

The optimal range of VFA:ALK can vary based on the application. For municipal systems, a healthy VFA:ALK ratio can range from 0.15 to 0.3 or even up 0.4 when implemented in conjunctions with biological phosphorus removal processes. Purely industrial applications may see slightly higher ranges where safe and healthy operation can be maintained.

Challenges to maintaining optimal digester performance where online VFA:ALK monitoring could provide early warning:

- Variable feed rates
- Blended or unknown feedstocks
- Heating and mixing efficiency
- Bacterial inhibitors (due to lack of nutrients or toxicity)

Anaerobic digesters at the Kenneth W. Hotz Water Reclamation Facility

Benefits

- Maximize value streams in recovering energy present in waste streams
- Minimize downtime (upsets) via immediate insight into the health of anaerobic digester systems in real-time

Hach EZ7250 Analyzer and EZ9130 Filtration System Overview

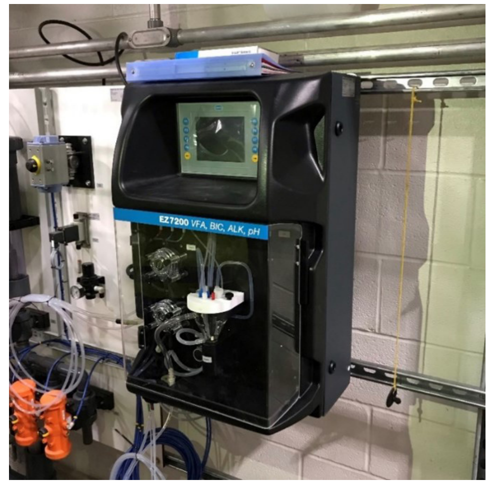
The plant staff regularly sampled the digester using following laboratory methods:

- VFA - Hach TNTPlus™ (TNT872) using the esterification method (Method 10240).
- Alkalinity – Buret titration, Standard Method 2320 B-97
- Bicarbonate – Not tested in lab
- pH – via pH electrode

To reduce laboratory time and effort as well as increase visibility into their anaerobic digestion process during non-laboratory hours, the EZ7250 was installed at a sample point on the primary digester recirculation line. The sample is fed through an integrated filtration system designed to handle the harsh nature of the sample with minimal maintenance (EZ9130 Heavy Duty Filtration System). From there the sample makes its way to the analyzer where automatic measurements of VFA, bicarbonate, alkalinity, and pH are taken in a single run with results as frequent as every 10-15 minutes (frequency is customizable). The instrument itself runs proprietary acid/base titration algorithms with low reagent demand and no volatilization for each sample and can be configured with automatic cleaning, calibration, validation, and priming sequences. The EZ7250 can be configured based on three standard ranges for each parameter measured to accommodate a wide range in operating applications. The county used a 5,000 mg/L standard for VFA's and a 100 meq/L standard for Alkalinity.

The plant installed the EZ7250 analyzer concurrent to their system startup in order to monitor the system performance. During the Cambi THP startup, the analyzer recorded significant and rapid changes in digester conditions.

During startup the plant was able to fine-tune the automated cleaning frequency for the instrument based on their specific site conditions to improve the analyzer's reliability and accuracy. Since then, the instrument has been continuously monitoring their digester health and performance. Based on the real-time nature of the system the plant has determined that they have enough additional capacity in their system to engage in conversations with private industries regarding accepting their industrial waste products.



View of the EZ7250 Analyzer – Online measurement of VFA, Alkalinity, Bicarbonate, and pH in a single run

"By being able to monitor conditions so closely with the analyzer, we were able to quickly optimize the feed rate at startup and needed much less seed sludge as a result.   Since the process has stabilized, we have been monitoring the trends and are able to quickly notice any changes. As a result, we have been able to react quickly to unexpected changes and make necessary adjustments to avoid any issues."

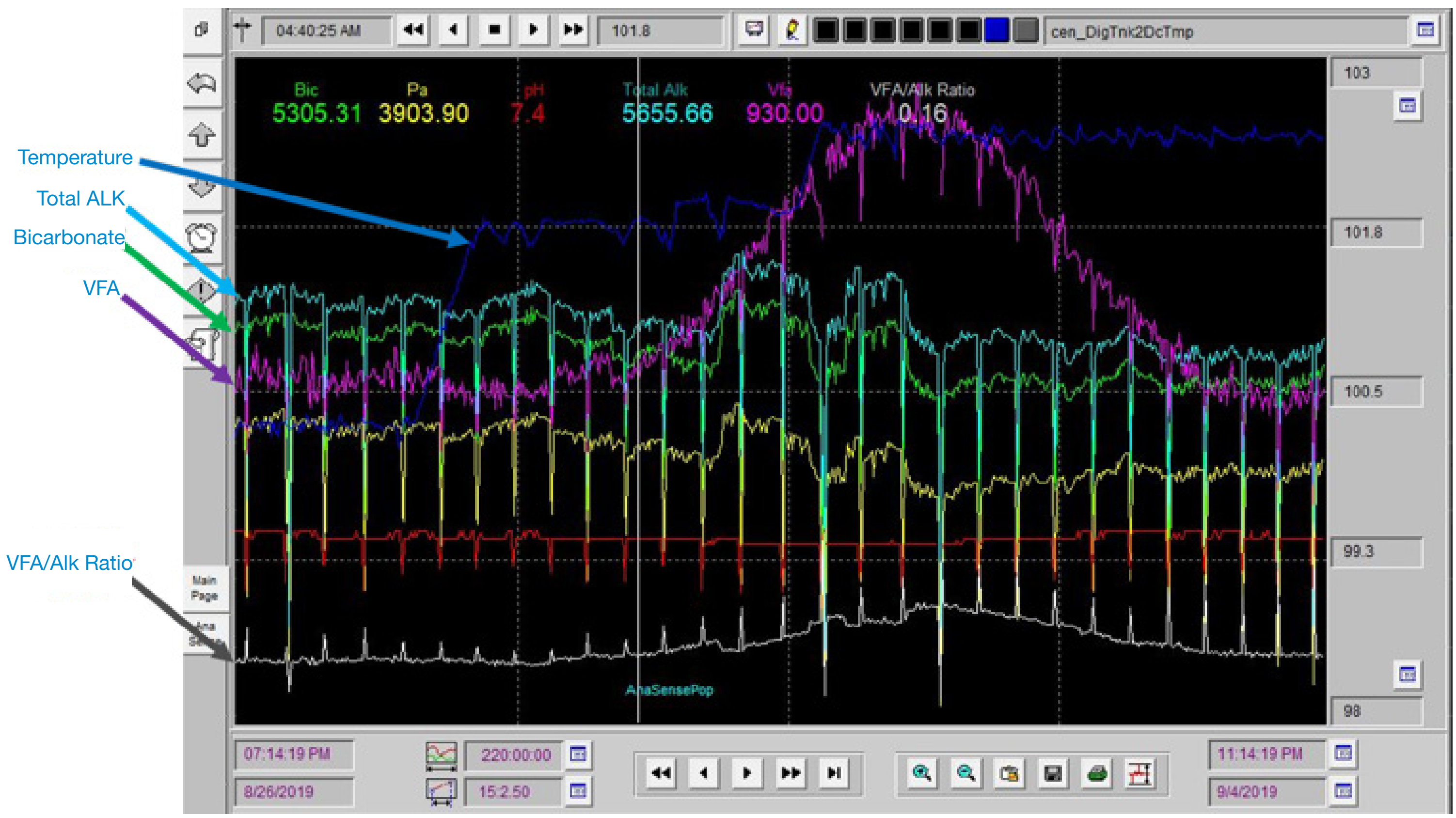
-Dawn Taylor, Assistant Superintendent

A Real-world Example

During normal operations in late summer 2019, the plant noticed a slight, but rapid increase in digester temperature. Since they had full real-time visibility of the digester health, they were able to monitor the performance. Online monitoring data from the EZ7250 provided insight that this slight increase in temperature indeed had a substantive impact on the digester biology, likely making the conditions a bit warmer than optimal for the methane forming bacteria, thus reducing their ability to keep up with the acid production. The trends showed increasing acid concentration in the digester. As a result, the plant was able to dial back digester feed to establish a new balance in the system, giving them time to allow the temperature to readjust to optimal conditions.

Engineering estimates predict a reduction in energy related costs of ~$1.5 million a year (roughly 30% of the facility's energy requirements). These savings coupled with the potential for additional biogas production and from industrial partnerships are not only enough to prevent rate increases for customers, but also help promote future adoption of sustainable resource recovery projects throughout the water treatment community.

Startup team and view of EZ9130 Heavy Duty Filtration Panel for use with Anaerobic Digesters



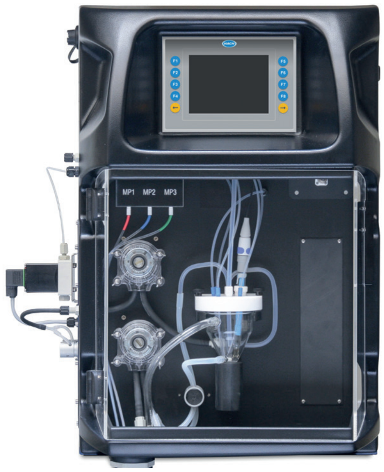
Online monitoring data from the EZ7250 showing that a slight increase in temperature had an impact on the digester biology.

Conclusions

Highly accurate and reliable online instrumentation for anaerobic digester health can provide the following benefits to system managers and operators:

- Minimize system upsets and downtime
- Maximize resource recovery efficiencies (where desired)

The EZ7250 Anaerobic Digester Monitoring solution, coupled with the EZ9130 Heavy Duty Filtration System, are ideally suited for any anaerobic digestion system and can provide real-time insights into the standard set of challenges faced by operators of anaerobic digesters in any industry.



EZ7200 Series VFA Analyzer

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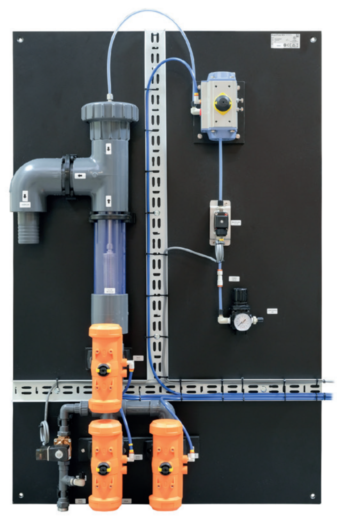

Universal self-cleaning filtration systems

Online Analysis Solutions

The EZ7200 Series VFA Analyzers are single-parameter titrators designed specifically for monitoring (wet) anaerobic digesters.

- EZ7250 VFAs, 10 - 500 mg/L as acetate equivalent, bicarbonate 1 - 50 meq/L or 5,000 mg/L as $CaCO_3$, total and partial alkalinity 1 - 50 meq/L or 5,000 mg/L as $CaCO_3$
- EZ7251 VFAs, 20 - 1,000 mg/L as acetate equivalent, bicarbonate 1 - 50 meq/L or 5,000 mg/L as $CaCO_3$, total and partial alkalinity 1 - 50 meq/L or 5,000 mg/L as $CaCO_3$
- EZ7252 VFAs 100 - 5,000 mg/L as acetate equivalent, bicarbonate 5 - 100 meq/L or 10,000 mg/L as $CaCO_3$, total and partial alkalinity 5 - 100 meq/L or 10,000 mg/L as $CaCO_3$
- EZ7253 VFAs 500 - 10,000 mg/L as acetate equivalent, bicarbonate 5 - 100 meq/L or 10,000 mg/L as $CaCO_3$, total and partial alkalinity 5 - 100 meq/L or 10,000 mg/L as $CaCO_3$

Options for all analyzers include:

- Multiple stream analysis (1-8 streams) reducing cost per sampling point
- Analog and/or digital outputs for communication

Laboratory Measurement Solutions

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