Volatile Fatty Acids monitoring for efficient and secured anaerobic digestion processes

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Abstract

Anaerobic digestion is a commonly used technology to process wastes from municipal, agricultural, or industrial sources. These processes consume organics and allows energy recovery via biogas production.

This ability to capture stored energy present in our waste streams makes anaerobic digestion an attractive technology, all the more for wastewater treatment plant which aim at becoming water resource recovery facilities.

While there are many specific configurations for anaerobic digesters (mesophilic, thermophilic, dry or wet…) the objective remains the same: create an environment that promotes the controlled and stable decomposition of organic matter via naturally occurring biological pathways

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. This is generally referred to as digester souring – an odor producing, time consuming, and expensive failure of the system.

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 the Acidogenesis step. Fortunately, bicarbonate alkalinity is produced as the methane-formers convert VFA into methane. Digester operators can maintain a healthy balance between VFA and alkalinity based on carefully monitored operational control of feed rates, mixing, and heating. That's why the ratio FOS/TAC (VFA concentration divided by alkalinity available) is a key parameter to monitor anaerobic digestion units.
While anaerobic digestion processes are well understood, digester upsets or inefficient energy recovery issues are still challenges commonly faced by operators.

This communication will illustrate benefits allowed by the monitoring of the ratio FOS/TAC in laboratory or with continuous online measurement, depending on the operator uptime and the degree of variability of the operational conditions.

First example illustrates FOS/TAC laboratory monitoring benefits for a digestor unit based in France and fed with agricultural products (CERES Germigny). Feedstocks of this facility are silage, hay and straw. Due to the seasonality of these products, the facility has storage capability to smooth the load. Produced biomethane is reinjected into the grid and is equivalent to the consumption of 3.000 inhabitants. Plant started up at the tarts beginning of 2020. In autumn 2020, the spreading of liquid digestate in fields from the reactor has reduced the active anaerobic biomass present within the reactor. The FOS/TAC ratio was the first indicator to illustrate the overloading of the reactor in comparison to the biomass presence. An immediate readjustment of the reactor feed rate helped the site to avoid the reactor souring and the killing of the remaining bacteria. A progressive restart of the digestor with a smooth increase of the inlet load guided by the trend of the FOS/TAC ratio was the perfect solution for an efficient recovery of the whole system at the design load in a limited timeframe (less than 30 days).

Second example demonstrates the advantages of on-line monitoring VFA analyzer on a Water Resource Recovery Facility (WRRF) located in north America. Medina county WRRF is equipped with an anaerobic digesters with Thermal Hydrolysis Pretreatment to maximize energy recovery. The digester is fed with sludge from the wastewater treatment line. Biogas produced allow power generation which is used for the water treatment line. To ensure optimal digester feed rates and to generally monitor digester health continuously, the operator chose to implement an online VFA measurement. 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. 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 VFA analyzer 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 and avoiding a breakdown of the digestion unit.

Keywords: VFA, Digestion, acidosis, monitoring

I. FOS/TAC monitoring in laboratory: feedbacks from CERES Germigny (France)

CERES Germigny digestor is fed with agricultural materials. A close monitoring of digestion process is performed to manage feedstocks quantities and reactor settings.

Figure 1. CERES Germigny digestor (FRANCE)

a. Material and method

The laboratory monitoring of the process is performed 3 times a week. This monitoring includes inlet organic load monitoring, pH, FOS/TAC ratio, ORP and temperature monitoring.

Samples are collected in 3 different locations of the digestion tank to check reactor homogeneity and modify in consequences if needed the mixing of the unit.

pH, ORP and FOS/TAC measurements are performed thanks to Hach titrator AT1000 which allows full set of results in few minutes.

Figure 2. One of the sampling points

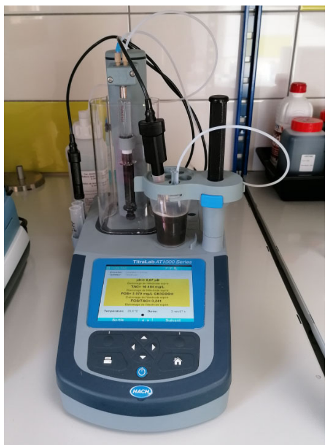

Figure 3. Hach AT1000 titrator

b. Illustrations of performances

Figure 4 illustrates the evaluation of FOS/TAC ratio according to empirical experience, with a suggestion to slow down or stop feedstock addition when FOS/TAC ratio is going up 0.6.

Figures 5 illustrates FOS/TAC ratio evolution along the weeks on CERES Germigny digestor. First weeks represents standard secured functioning of CERES digestor, with a FOS/TAC ratio below their objective of 0.6.

Then in October 2020, a high excess sludge removal from the reactor was performed, leading to an unbalanced feedstock quantity in relation to the active anaerobic biomass present within the reactor. The immediate increase of the FOS/TAC ratio is visible as a direct consequence of an overloading of the reactor in comparison to the active biomass present. An immediate readjustment of the reactor feeding allowed avoiding the reactor souring and the killing of the remaining bacteria. A progressive restart of the digestor with a smooth increase of the inlet load, guided by the evolution of the FOS/TAC ratio, allowed for an efficient recovery of the whole system at the design load in a limited timeframe (less than 30 days). Mid of December, FOS/TAC ratio increased again. Reactor souring was this time avoided thanks to immediate dosing of carbonate to provide alkalinity to the digestor.

Evaluation of FOS/TAC ratios according to empirical experience

FOS/TAC ratios	Background	Suggestion/Counter Action
>0,6	Highly excessive biomass input	Stop adding biomass
0,5-0,6	Excessive biomass input	Add less biomass
0,4-0,5	Plant is overflowing	Monitor the plant more closely
0,3-0,4	**Biogas production at the maximum**	**Keep biomass input constant**
0,2-0,3	Biomass input is too low	Slowly increase the biomass input
<0,2	Biomass input is far too low	Rapidly increase the biomass input

Figure 4. FOS/TAC ratio according to empirical experience

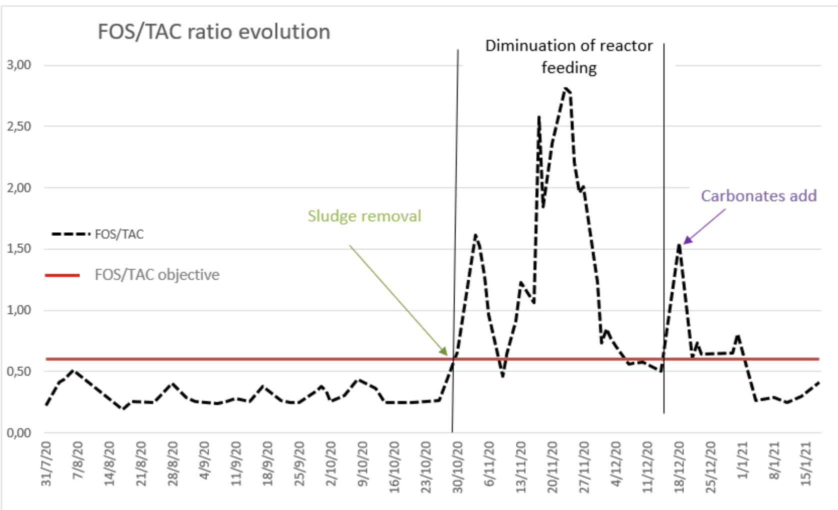

Figure 5. FOS/TAC ratio monitoring along the weeks with illustration of events

II. FOS/TAC online monitoring: feedbacks from Medina County (US)

Medina County Water Resource Recovery Facility wanted to ensure optimal digester feed rates and to generally monitor digester health continuously. They wanted to implement online monitoring technologies to supplement the standard laboratory procedures used in monitoring the health of anaerobic digesters (grab samples for VFA, alkalinity, and pH).

Figure 6. Anaerobic digesters at the Kenneth W. Hotz Water Reclamation Facility

a. Material and method

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 can be configured with automatic cleaning, calibration, validation, and priming sequences.

Figure 7. The EZ-7250 online analyser installed on Medina WWTP

Figure 8. The EZ9130 sample preparation unit upfront the VFA analyzer

b. Illustrations of performances

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

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. It avoided them a complete break-down of the digestor which would have led to extra electrical costs.

These security checks, 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

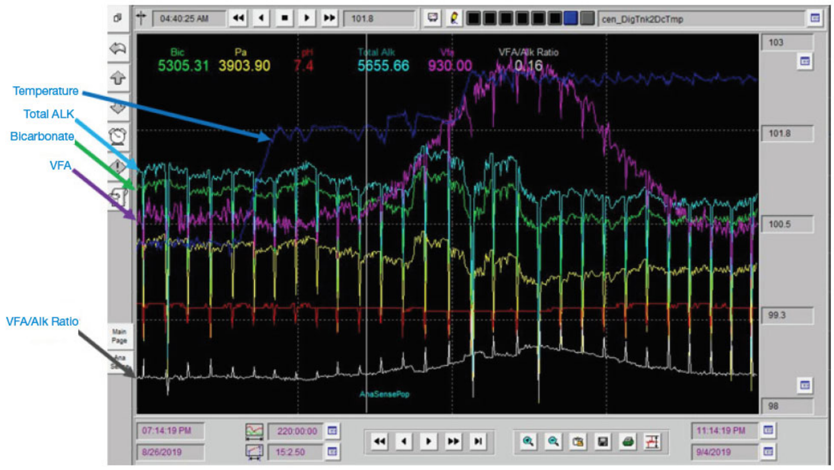

Figure 9. Online monitoring data from the EZ7250 showing that a slight increase in temperature had an impact on the digester biology.