# SENTRY SENSOR FOR ANALYSIS OF ANAEROBIC DIGESTION PERFORMANCE CNETE- REVIEW


7/25/2018

Initial SENTRY Report on AD performance monitoring

SENTRY

# 1. Contents

INITIAL SENTRY REPORT ON AD PERFORMANCE MONITORING

# 1. Executive Summary

The SENTRY system was installed July 2017 at CNETE (Centre National en Electrochimie et en Technologies Environnementales) or National Center in Electrochemistry and Environmental Technologies testing facility in Quebec, Canada. A system was installed in two duplicate Anaerobic Digesters processing waste activated sludge. A pre-treatment step was added to one of the reactors, and the differences between the systems were analyzed using a SENTRY system installed in each. The sensor is demonstrated to be a key tool in understanding the conditions in test and control AD systems. For continuing anaerobic digestion activities the sensor could be applied to

(1) Characterizing the impact of pre-treatment on influent wastewater streams,

(2) Providing correlations to real-time biogas production and

(3) Optimizing feed cycle times to ensure removal of bio-available carbon.

The major conclusions from the report are outlined as follows:

**Characterizing impact of pre-treatment:**

- The pre-treatment accounted a 22.9% increase in biogas production between the test and control system. Further analysis of fractionation of the remaining organic material could be beneficial for understanding the full effect of the pretreatment.
- The pre-treated wastewater showed more consistent activity throughout the week, suggesting the pretreatment was having a good effect of maximizing the biological activity in the reactor. This also suggested that a potentially longer HRT could produce even higher biogas production and removal rates.

**Biogas production:**

- Biogas production (and therefore reactor activity) trended well with SENTRY output. This shows great promise as a way to fill in the gaps of data that exist in daily sampling.
- This biogas trend was especially helpful for understanding reactor A (no pretreatment) as the batch mode beginning and end was clearly noticed (typically between noon and 7pm). IWT believes additional loading to this reactor could be achieved during times of low MET.
- The pretreatment step has clearly increased the potential for biogas production of the microbes based on the current HRTs of the reactor.

**Process feeding monitoring:**

- The SENTRY sensors were able to pick up distinct batch run cycles for each system. 3 times higher average biological activity (MET) and longer cycles were noted in the reactor receiving the pre-treated influent (reactor B), suggesting a more biologically active feed material.

- The sensor displayed the weekly patterns of the feed cycle and response to the feed cycle in real time with sensors placed inside the reactors. Feed dates/times can be observed, as well as when reactions inside the system had slowed down.
- SENTRY data provides operator the option to optimize feeding cycles more closely to MET output. Waiting for BES data to return to baseline would be a suitable strategy for optimized cycle times.

## 2. General Site Information

The SENTRY system is installed at CNETE testing facility. A feed tank feeds two similar reactors receiving waste activated sludge (WAS). In June 2018, CNETE started doing pre-treatment to the WAS fed into Reactor B, keeping Reactor A on the non-pretreated WAS. Figure 1 shows the experimental setup.

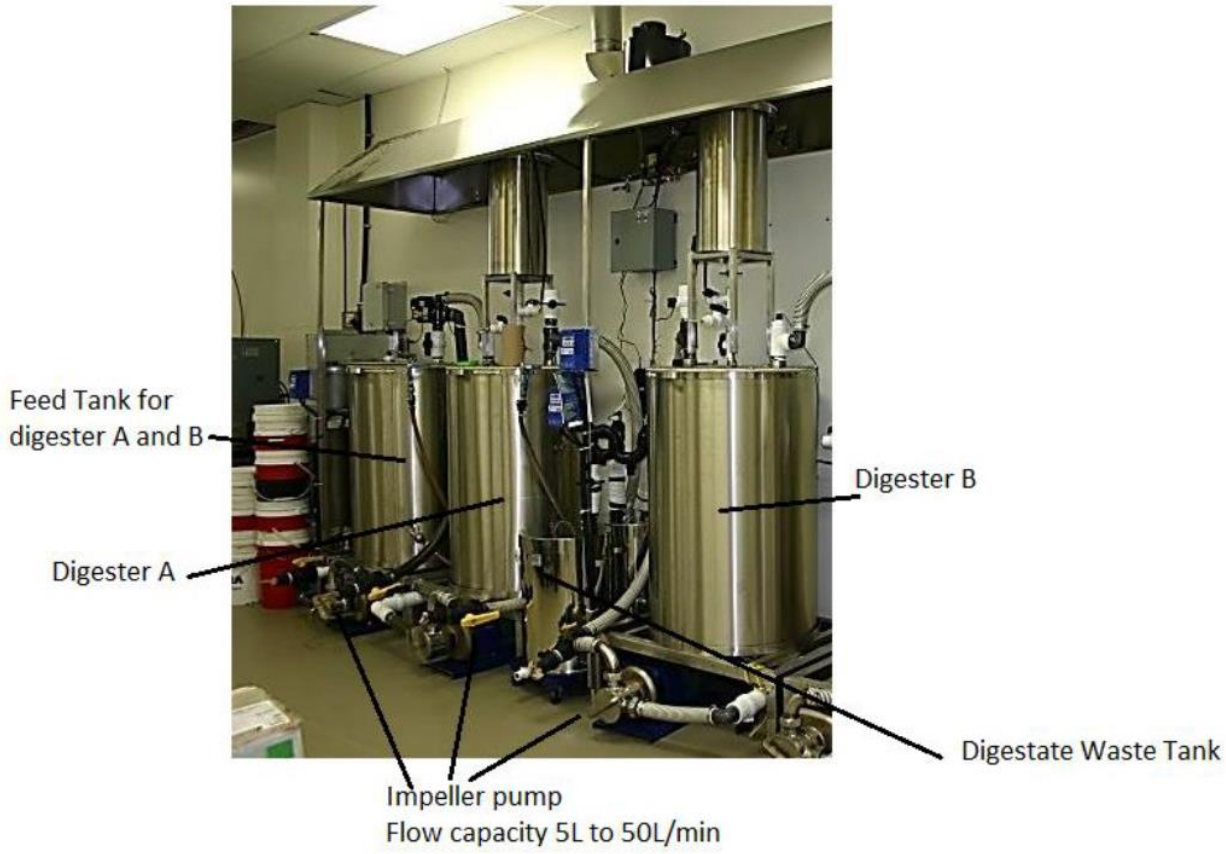


**FIGURE 1: IMAGE OF REACTOR SETUP**

# 3. SENTRY Installation and Testing Schedule

The IWT team worked with CNETE to install the sensors in July 2017. The reactors did not have any ready to use ports which would have allowed direct contact with the reactor liquid. An unused viewport in the top of the reactor was identified as a location and IWT custom manufactured a mount to hold the sensor in place through this viewport, as shown below.


**FIGURE 2 THE LEFT IMAGE IS A 3D DRAWING OF THE CUSTOM MOUNT AND BES SENSOR. THE RIGHT IMAGE IS A PICTURE TAKEN OF THE INSTALLED CONTROL PANEL**

The SENTRY sensors measure Microbial Electron Transfer (MET), which is an instantaneous measurement of microbial activity in the wastewater. As the exo-electrogenic microbes digest wastewater they respire electrons onto the SENTRY electrode. In higher strength wastewater streams this MET measurement correlates well with Volatile Fatty Acid (VFA) and information can be used to predict fluctuating concentrations over time.

CNETE provided testing results from their laboratory for the system. Their testing was done weekly on the composition of the influent and reactors and biogas sampling was carried out several times a week.

# 4. SENTRY Data

The SENTRY Online Dashboard allows Island Water Technologies and the client to easily monitor the status of the probes installed in their system. Figure 3 below is a visual representation of the dashboard for probe CN2 (reactor A) and CN4 (reactor B) from July 4th to July 18th.

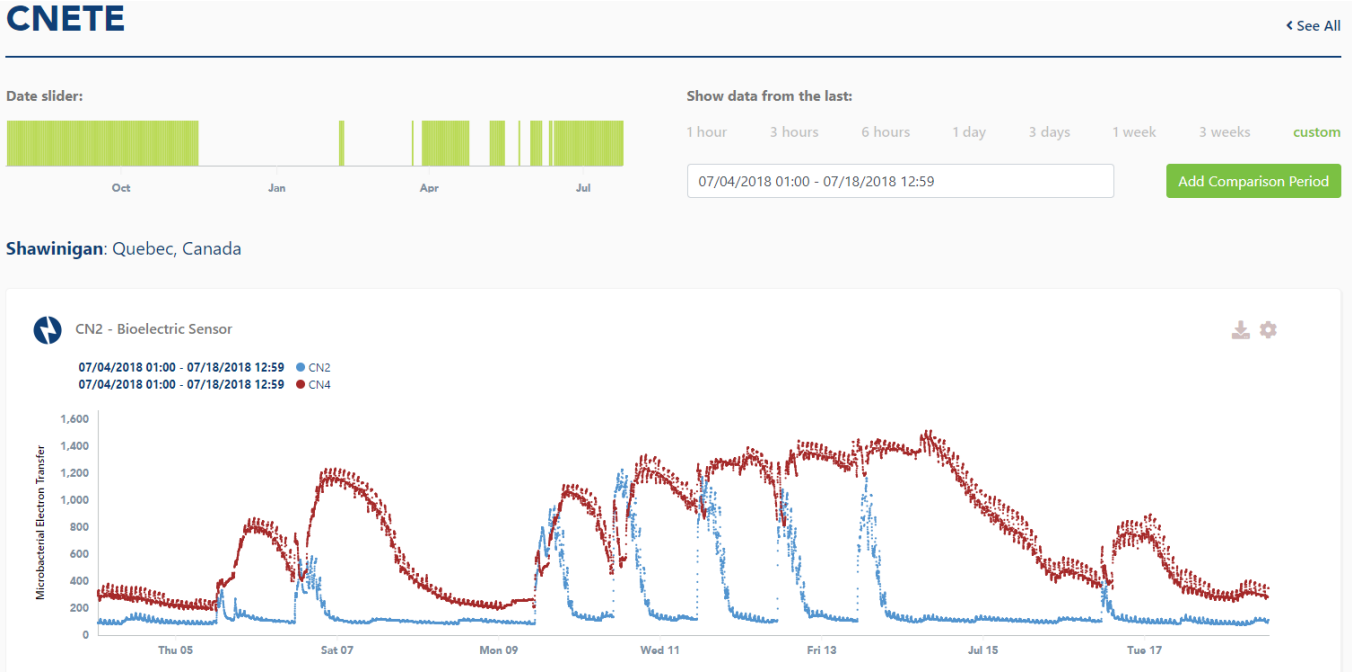


**FIGURE 3 DASHBOARD VISUALIZATION OF DATA FROM THE SERVER FROM JULY 4TH TO JULY 18TH BLUE IS REACTOR A AND RED IS REACTOR B**

## 4.1. Full Data Set

The SENTRY system was installed at CNETE in July 2017, however on June 12, 2018 they began a new experiment where reactor A was left as a typical batch reactor to be used as a control system and reactor B received wastewater that underwent a pretreatment phase prior to entering the reactor. The SENTRY output for Reactor A and B for the study period are shown in Figure 4 and 5 respectively.

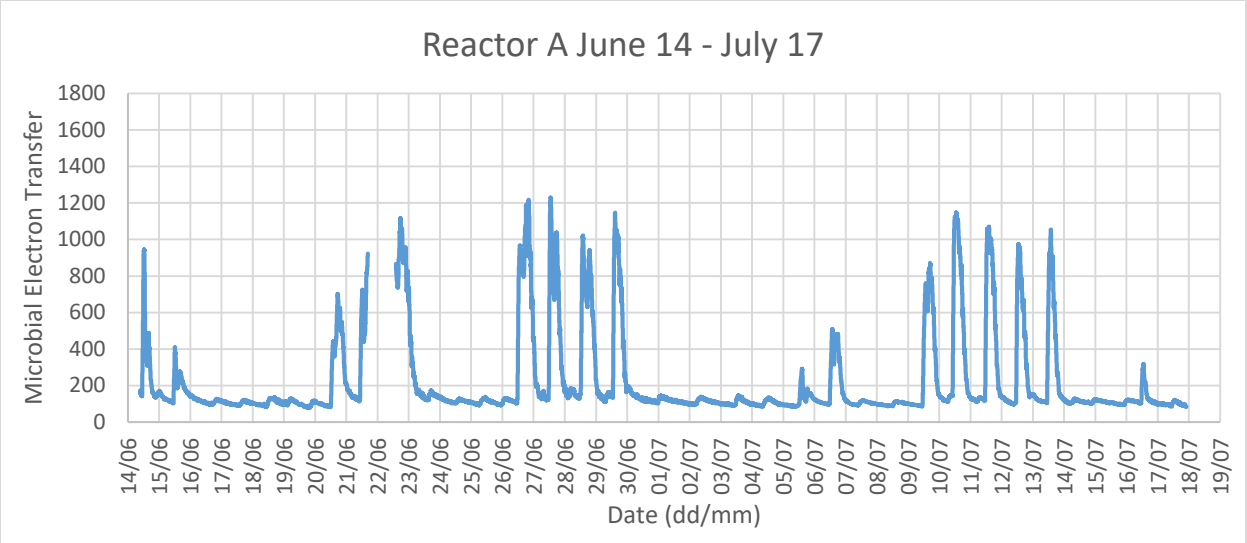


**FIGURE 4 REACTOR (CN2-REACTOR A). BATCH CYCLES ARE CLEARLY OBSERVED, BOTH THE START AND LENGTH OF CYCLE.**

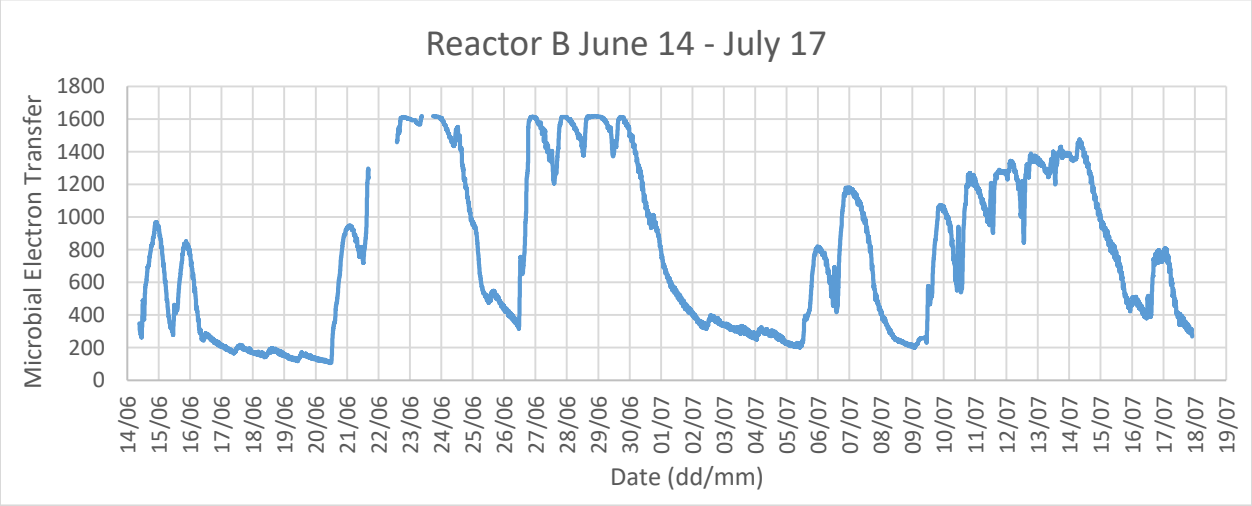


**FIGURE 5 REACTOR (CN4 REACTOR B). START TIMES OF THE CYCLES ARE CLEARLY OBSERVERED. THE SENSOR PICKED UP PULSES DURING THE FEEDING EVENTS.**

- Reactor A and B behaved similarly (were run in duplicate and had very similar performance) before the shift in the type and frequency of feed to reactor B.
- Reactor A shows the change in microbial activity in each batch feed cycle. There is a clear start and end to each cycle with a return to baseline activity between each cycle.
- Reactor B does not return to baseline between each feeding. It is proposed from the increased and more consistent SENTRY output that the pre-treatment of feed solution has increased the presence of bio-available organics.

## 4.2. Weekly Overlay

By overlaying the four weeks of the study period from Sunday to Saturday we can see a clear and repeating pattern: for each batch in reactor A, and each pulse feeding for reactor B.

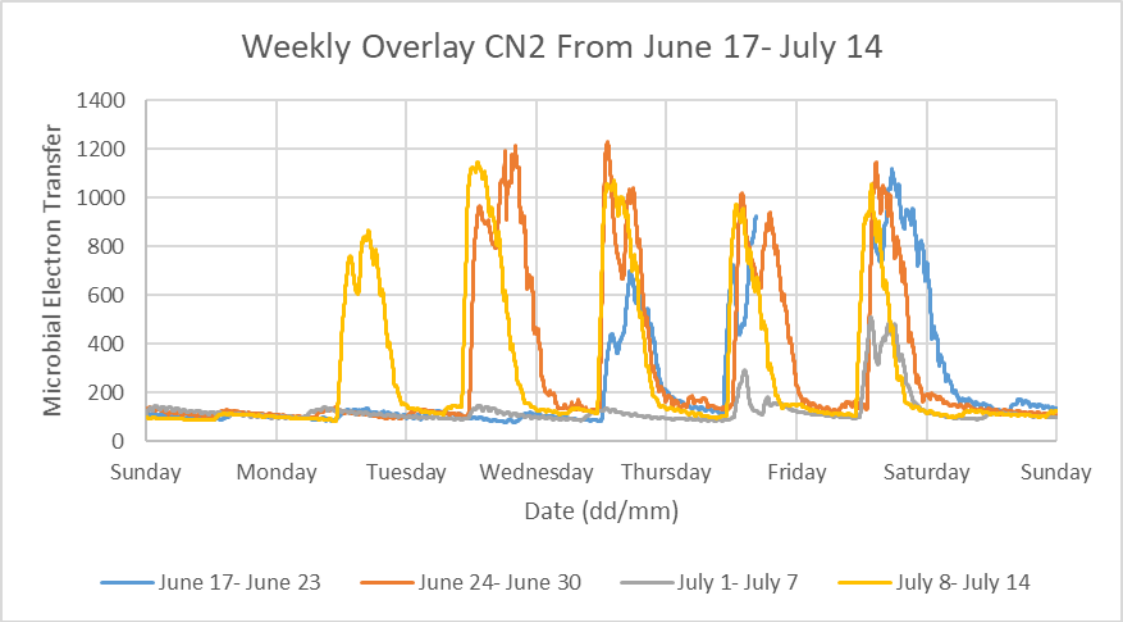


**FIGURE 6 WEEKLY OVERLAY OF CN2 (REACTOR A) DATA FROM JUNE 17-JULY 14TH. THE WEEKLY FEEDING PATTERN IS CLEARLY OBSERVED**

- 2-5 batch cycles were observed each week.
- The first cycle tended to have lower MET than the following cycles.
- Each batch was started around noon each day and typically peaked at 5-7PM and took until midnight to return to baseline MET.

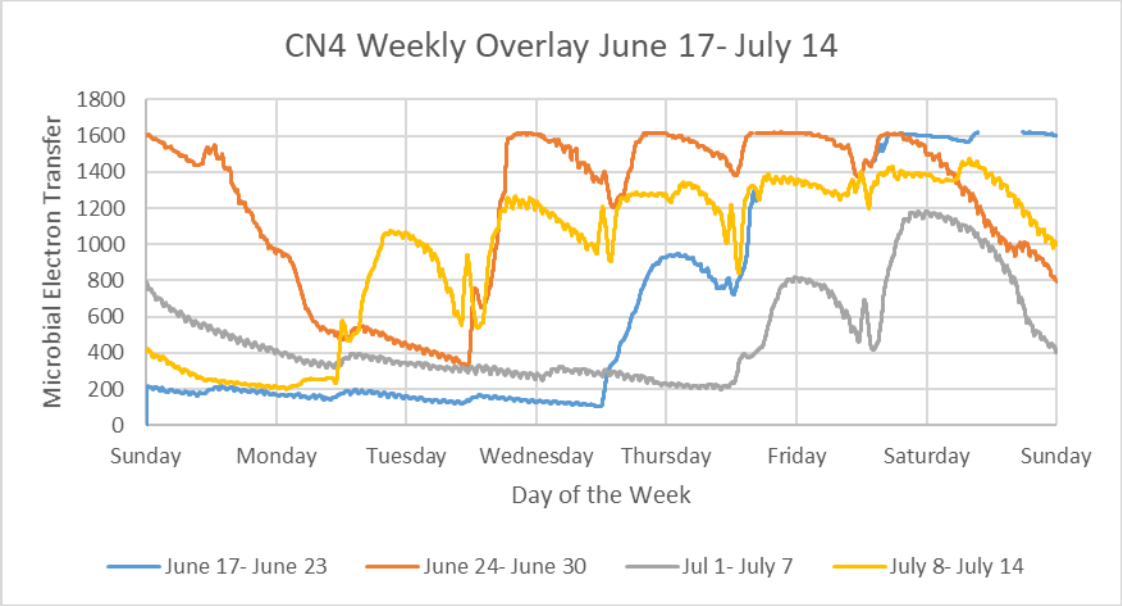


**FIGURE 7 WEEKLY OVERLAY OF CH4 (REACTOR B) DATA FROM JUNE 17TH - JULY 14TH**

- A feed cycle is observed
- Reactor B had significantly higher MET after the shift in feed. An increase around noon each day can still be seen along with a peak at 5-7PM, however the high MET is sustained until midnight when it slowly decreased by only 200-400 MET before increasing again at noon with the next feeding.

## 4.3. Reactor Comparison

Figure 8 and 9 compare the reactor performance using sample data provided by CNETE for the study period.

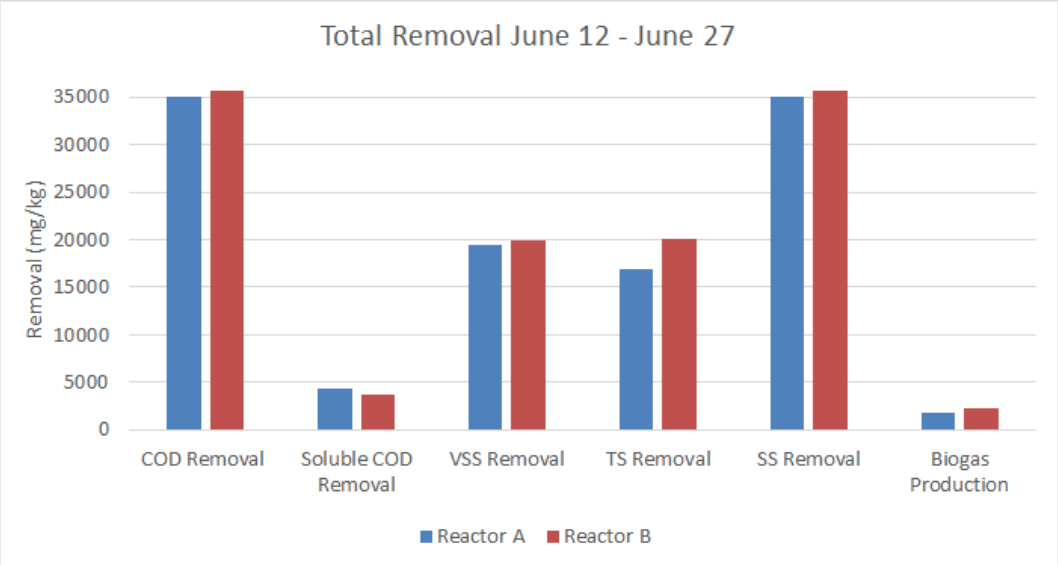


**FIGURE 8 COMPARISON OF TOTAL REMOVAL OF FIVE PARAMETERS FOR REACTOR A AND REACTOR B**

- Reactor B has slightly higher removal rates than reactor A since the change in operation on June 12th.
- Soluble COD removal is the only parameter reactor A is outperforming reactor B on. This may be due to the pretreatment step before reactor B converting complex COD into soluble COD, explaining why total COD removal is higher in reactor B but soluble COD removal is less in reactor B.
- The sample data supplied for the study period ended on June 27.

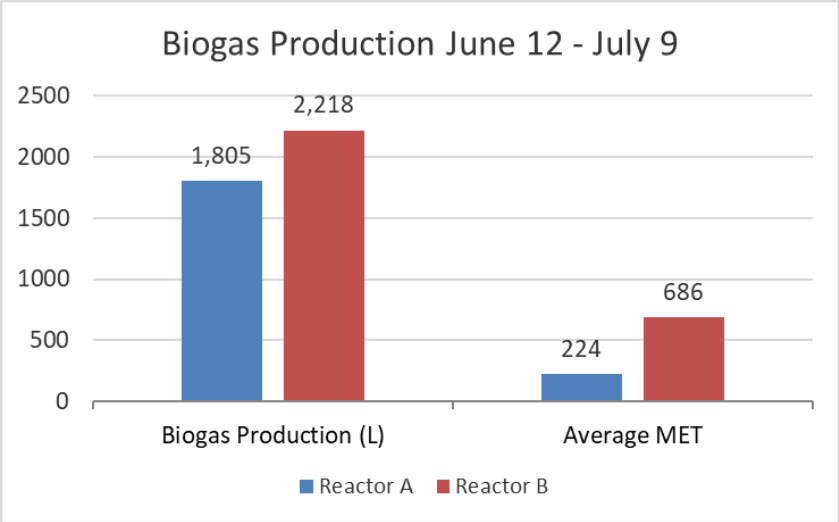


**FIGURE 9 BIOGAS PRODUCED OVER THE STUDY PERIOD IN EACH REACTOR COMPARED TO THE AVERAGE MET OVER THE STUDY PERIOD OF EACH RACTOR**

- Biogas production was 22.9% higher in reactor B for the study period.
- The MET was averaged over the entire study period to show the different levels of activity in each reactor. Reactor B has 3 times higher average MET than reactor A.

## 4.4. Biogas Correlation to MET

Figure 10 and 11 compare the daily biogas production with the 1 hour average MET and the 24 hour average MET.

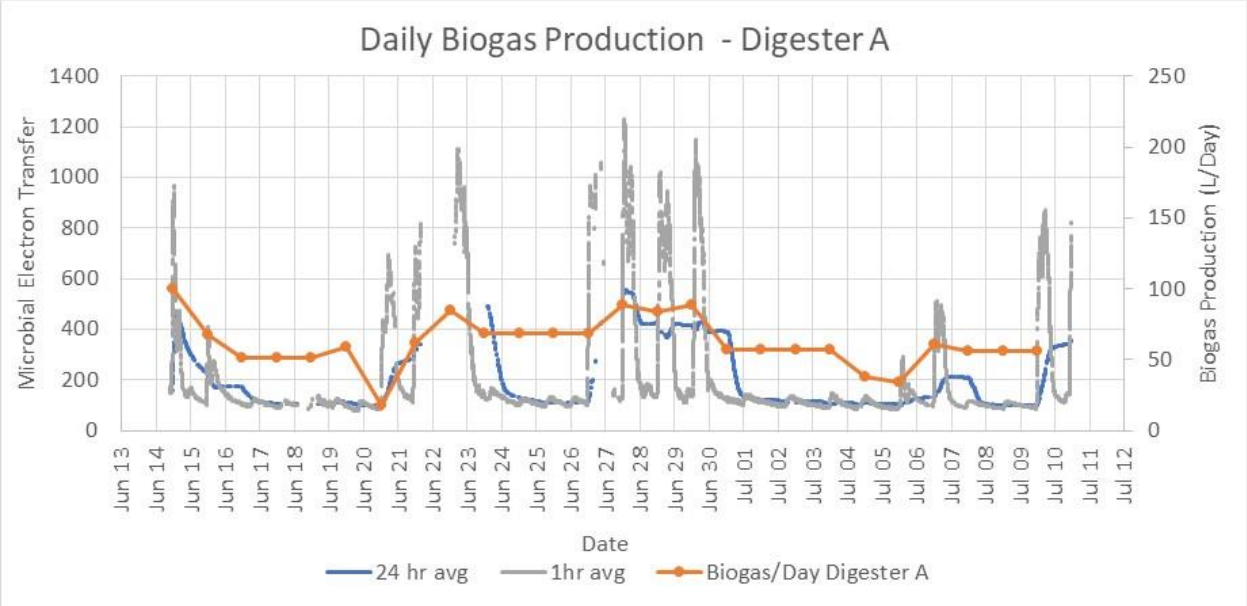


**FIGURE 10 DAILY BIOGAS PRODUCTION OF REACTOR A VS. SENTRY OUTPUT (CN2). BIOGAS PRODUCTION (AND THEREFORE REACTOR PERFORMANCE) MATCHES WELL WITH SENTRY OUTPUT. THE 24 HOUR AVERAGE SENTRY**

**MATCHES THE DAILY MEASURING OF BIOGAS, WITH THE 1 HOUR AVERAGE PROVIDING ADDITIONAL LATENCY OF REAL TIME PERFORMANCE**

- Daily biogas samples were taken between 11:30 and 13:30 each day. For the biogas comparison to MET, it was assumed that all biogas samples were taken at noon.
- The 24 hour average MET trends better with the daily biogas values than the 1 hour average MET values. It shows that although daily biogas production is fairly steady, the biological process taking place is not.
- It could be assumed that the majority of the daily biogas production is occurring from noon to 7PM. This may be an opportunity
- For batch processes which is <24 hours a daily sample is difficult to determine what exactly is happening during each batch. The SENTRY probe can give extra insight into what is happening during each treatment batch. It gives operators instant and continuous feedback on the microbial activity in the system.
- Total biogas values were taken 3-4 times per week and the difference was used in this analysis for daily biogas. For the days biogas totals were not recorded, the total for the following day was averaged over the number of days not sampled on. If there was a sample taken each day the biogas production would trend better with the 24hr MET over the entire study period.

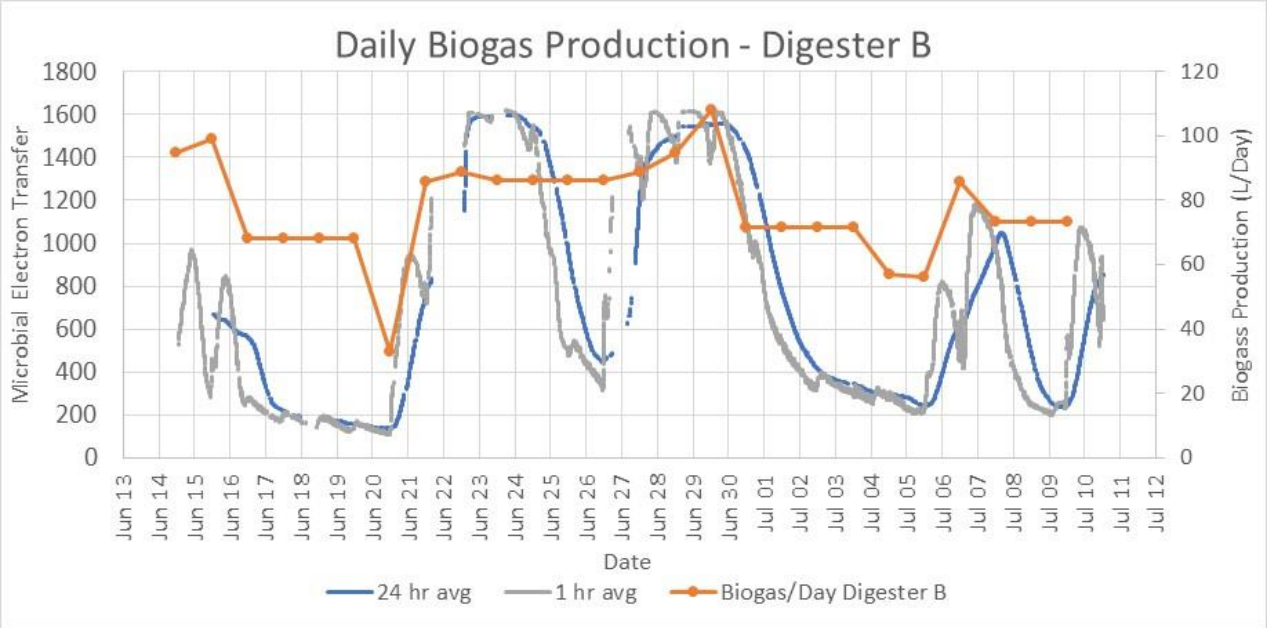


**FIGURE 11 DAILY BIOGAS PRODUCTION OF REACTOR B VS. SENTRY OUTPUT (CN4). BIOGAS PRODUCTION (AND THEREFORE REACTOR PERFORMANCE) MATCHES WELL WITH SENTRY OUTPUT. THE 24 HOUR AVERAGE SENTRY MATCHES THE DAILY MEASURING OF BIOGAS, WITH THE 1 HOUR AVERAGE PROVIDING ADDITIONAL LATENCY OF REAL TIME PERFORMANCE.**

- For Reactor B, the 1 hour average MET and the 24 hour average MET are trending better due to the pulse feeding happening in reactor B for the study period.

- Compared to Reactor A, Reactor B has a significant increase in MET during this testing period.
- Due to this increased MET and the fact that the reactor produced an additional 22.9% biogas, it is hypothesized that increased retention time in this reactor would further increase COD removal.
- The average daily biogas over the days with no samples taken causes the biogas to deviate further than expected from the 24 hour average MET values.

# 5. Conclusion

Output from the sensor was demonstrated to be strongly correlated to biogas production from the test and control reactors. The sensors were demonstrated to be a key tool in understanding both the impact of pre-treatment on the suitability of the waste organics for AD processing and understanding / optimizing feeding cycles to maximize utilization of bio-available organics.

The pre-treatment increased the bio-available carbon in the wastewater stream and was accounted for with a 22.9% increase in biogas production. The sensor output for test and control systems correlated the increased production but also allowed operators to view in real-time the impact of feeding cycles.

**The sensor is demonstrated to be a key tool in understanding the conditions in test and control AD systems. For continuing anaerobic digestion activities the sensor could be applied to**

**(1) Characterizing the impact of pre-treatment on influent wastewater streams,**

**(2) Providing correlations to real-time biogas production and**

**(3) Optimizing feed cycle times to ensure removal of bio-available carbon.**