# From poop to gold: an examination of energy-positive wastewater treatment in an anaerobic reactor system

**Daniel Lucio, Andrew Pfluger, Jennie Callahan, Brett Van Houghton, Junko Munakata-Marr, Linda Figueroa**

Engineering Research Center (ERC) for Re-inventing the Nation's Urban Water Infrastructure (ReNUWIt)

& Department of Civil & Environmental Engineering, Colorado School of Mines

## SUMMARY

Today's current best practices for wastewater treatment involve aerobic processes that require substantial amounts of energy. Best practice aerobic wastewater treatment facilities with anaerobic digestion of biosolids are able to produce 500-700 kWh/MG, which is approximately one-third to one-half of the 1500-2000 kWh/MG used to operate the facility. On the other hand, primary anaerobic treatment has the potential to be energy-positive by using methane gas produced by anaerobic microbial communities in the system. Previous results from the pilot-scale four-compartment anaerobic hybrid reactor (anaerobic baffled reactor (ABR) – anaerobic fixed film reactor (AFFR)) at Mines Park suggest that the multiple-compartment configuration enhances COD and TSS removal while generating stoichiometric amounts of methane. Additional advantages of anaerobic wastewater treatment in multiple-compartment reactors include the production of less biosolids and low energy usage. The purpose of this research is to characterize the ABR-AFFR for COD removal, TSS removal, and methane generation during the month of July when high temperatures (22-25 ˚C) are observed. COD and TSS removal is compared to the EPA 7-day secondary standards (45 mg $BOD_5$/L and 45 mg TSS/L). Methane flowrate is also evaluated for trends and converted to theoretical energy values. Results suggest that the ABR-AFFR is able to achieve the 7-day EPA secondary standards for $BOD_5$ and TSS under summer conditions, while generating enough methane to theoretically power the reactor system.

## STUDY LOCATION & EXPERIENCES


## STUDY APPROACH

- The Mines Park hybrid reactor consists of a three-compartment anaerobic baffled reactor (ABR) coupled to an anaerobic fixed film reactor (AFFR). The ABR-AFFR has been operating for over 600 days.
- Characterization includes: temperature, pH, alkalinity, COD (total, soluble, particulate), TSS, VSS, $BOD_5$, TOC, DOC, nitrogen ($NO_3$, $NO_2$, $NH_4$, TN, TKN, Organic N), phosphorus (TP, $PO_4$), Sulfur ($H_2S$, $SO_4$), biogas ($CH_4$ and $CO_2$, biogas flowrate, dissolved $CH_4$), VFAs (acetate, propionate), trace metals, and energy use. DNA analyses include qPCR.

## REACTOR CONFIGURATIONS

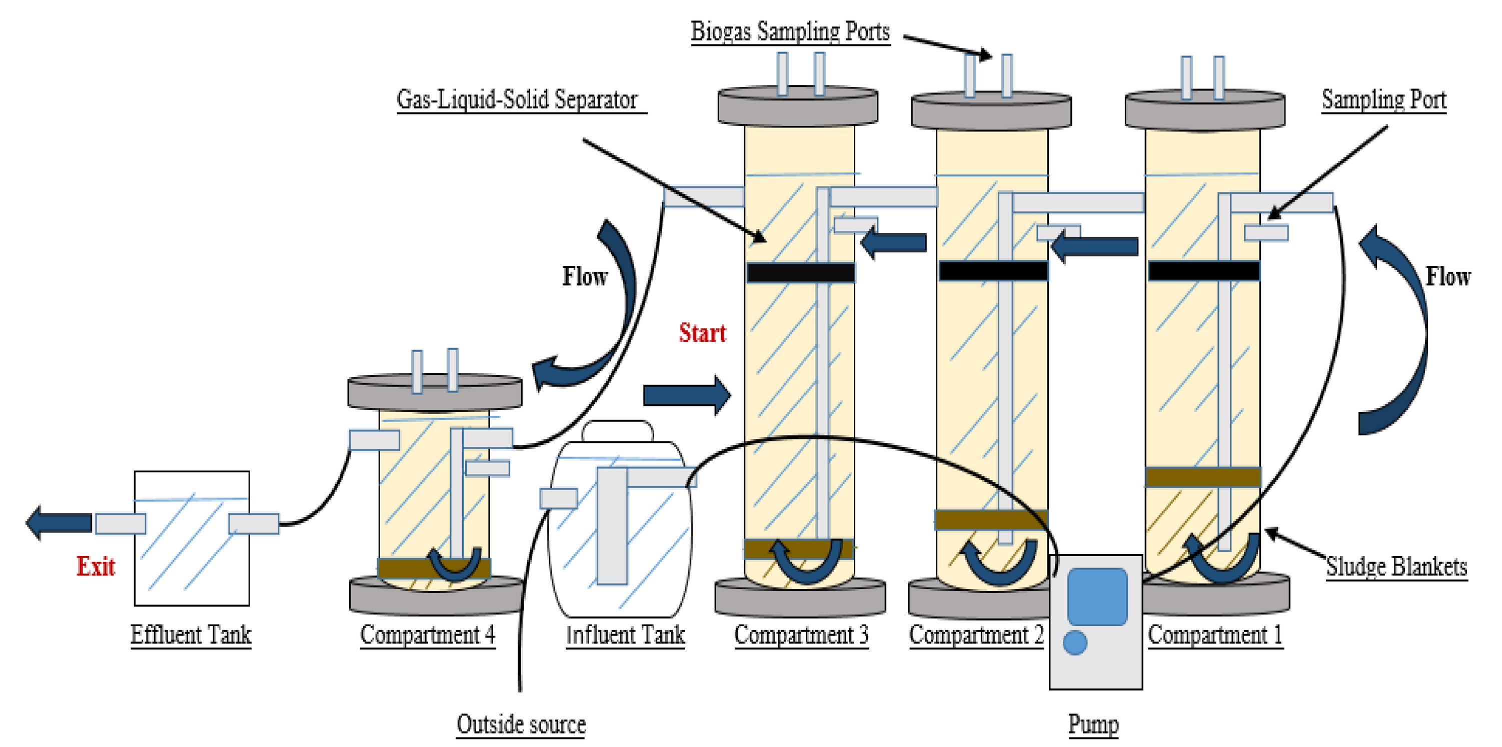


**Figure 1 – Schematic**. The Mines Park ABR-AFFR hybrid reactor consist of three cylinder-like compartments with a height-diameter ratio of 12':1' that each hold a volume of 230 liters, and a fourth compartment that has a height-diameter ratio of 4':1' that holds a volume of 80 liters, for a total volume of 770 liters. The system treats 770 liters of domestic wastewater per day and has a total hydraulic retention time of 27 hours. Energy is only used to run the water pump and computer system used for monitoring.

## STUDY RESULTS

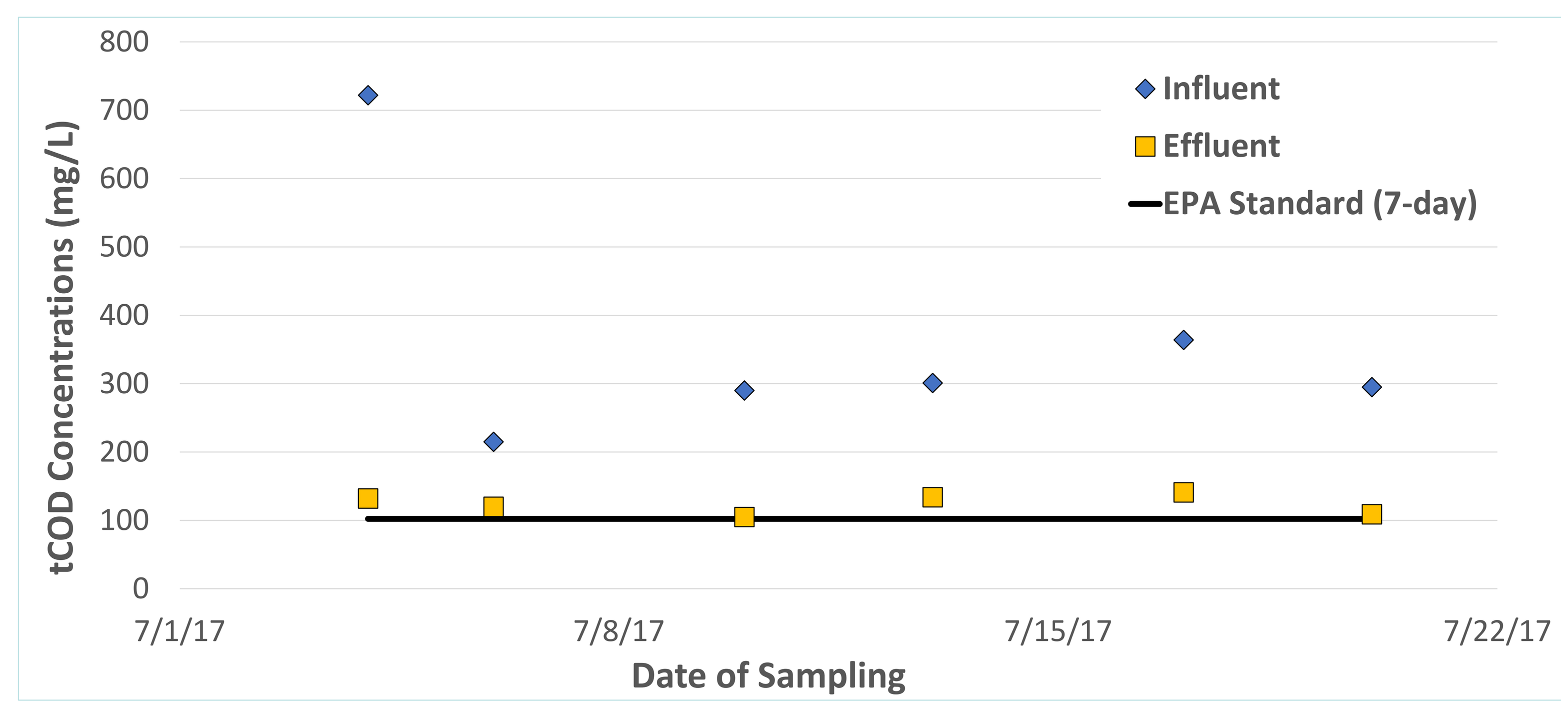


**Figure 2 – COD Concentrations.** Comparison of the total COD (tCOD) concentrations before and after treatment compared to the adjusted to the EPA 7-day secondary standard (45 mg $BOD_5$/L, in terms of COD (i.e., 102.3 mg/L for this reactor system)). The mean temperature was 22-25 ˚C during the period of study. The reactor system came close to or achieved the EPA's secondary standard at several time points.

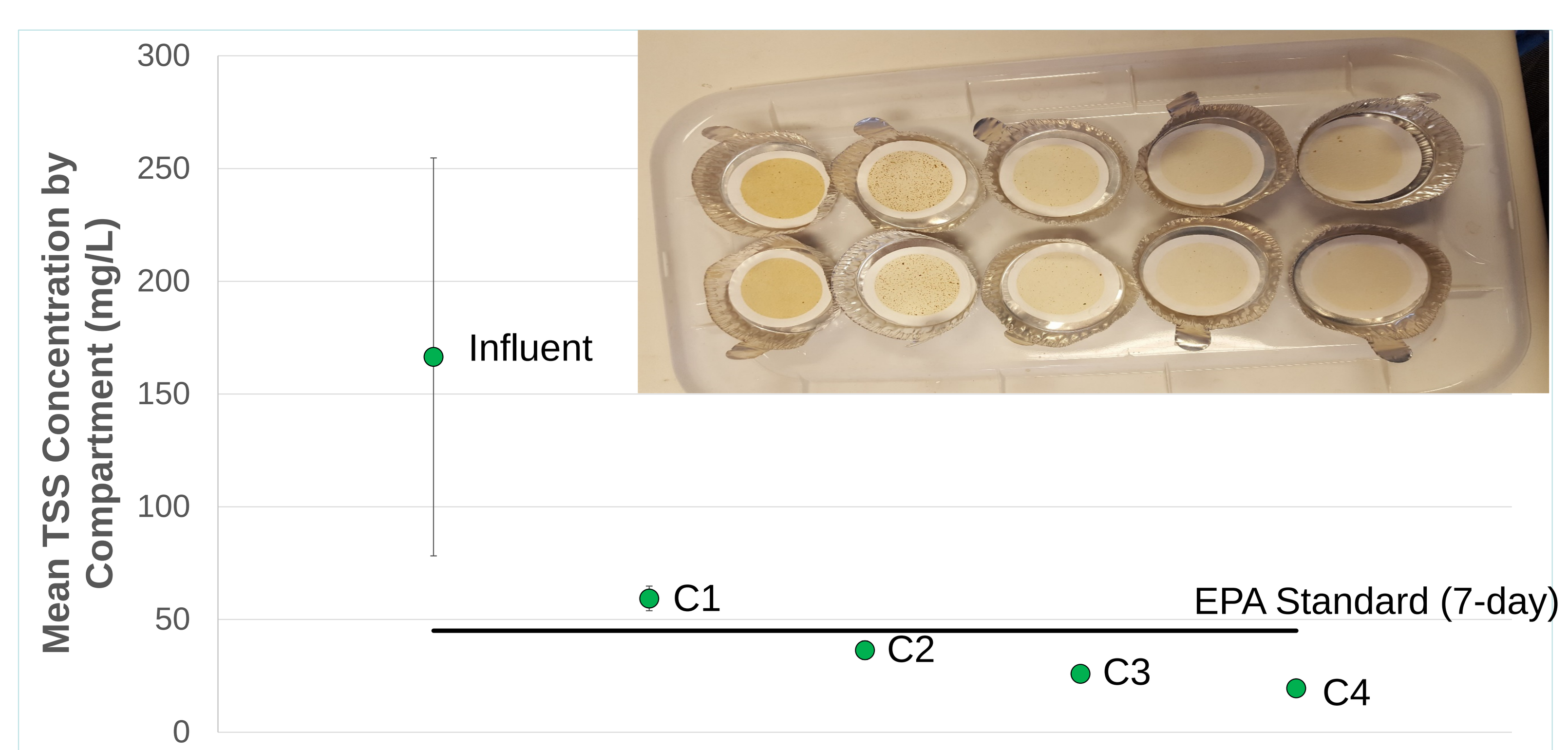


**Figure 3 – Total Suspended Solids Concentrations**. Comparison of mean total suspended solids (TSS) concentrations in each reactor compartment during the month of July 2017 compared to the EPA 7-day secondary standard (45 mg TSS/L). TSS concentrations decreased sequentially through each compartment of the reactor. Influent TSS concentrations were highly variable; however, effluent concentrations (i.e., C4) were consistent throughout the study (20 mg/L).

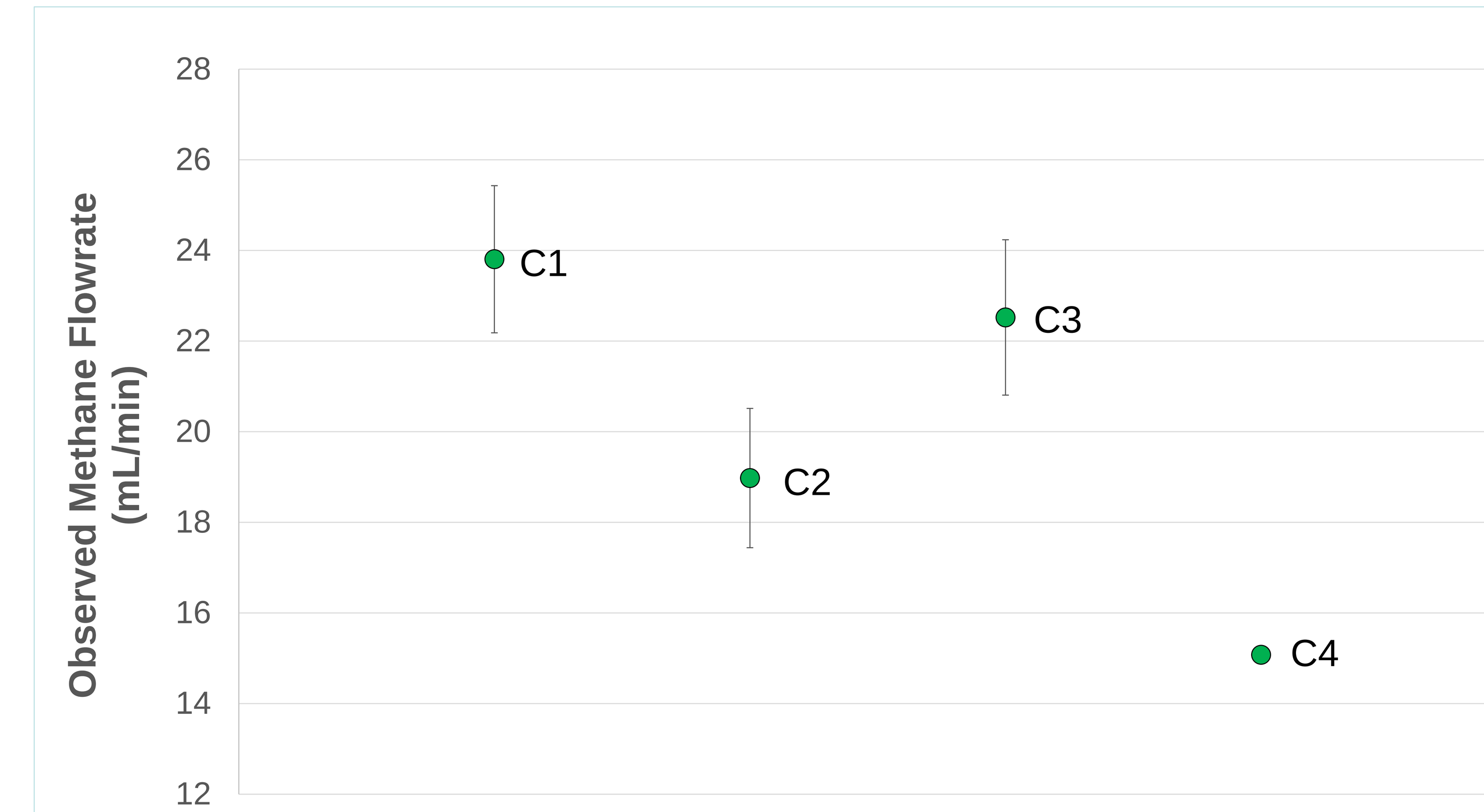


**Figure 4 – Observed Gaseous Methane Flowrate**. Observed methane flowrate by reactor compartment during the month of July (n = 3 sampling points; C4 = 2 valid sampling points). C1 and C3 produced the most methane, which relates to sludge volume and % relative abundance of methanogens in each compartment. The mean system-level methane flowrate was 80.4 ± 5.7 mL/min.

## NET ENERGY BALANCE

| Date | kWh Produced | Observed Energy Used (kWh) | Excess Energy Produced (kWh) |
|---|---|---|---|
| 3-Jul-17 | 0.102 | 0.0293 | 0.07 |
| 11-Jul-17 | 0.127 | 0.0293 | 0.10 |
| 18-Jul-17 | 0.141 | 0.0293 | 0.11 |

**Table 1- Net Energy Balance.** The observed methane flowrate, when converted to electricity (35.8 kJ/L @ STP) using conventional assumptions and calculations, exceeds the energy demand for the system, thereby creating an energy-positive scenario.

## IMPLICATIONS AND WAY AHEAD

- The anaerobic reactor system was able to achieve EPA 7-day secondary standards for TSS (≤ 45 mg/L) and for $BOD_5$ (≤ 102.3 mg tCOD/L) during the month of July (ambient temperatures = 22-25˚C).
- Evaluation of system integration options of mainstream anaerobic technologies is needed to facilitate a shift from energy-intensive aerobic treatment processes to energy-positive anaerobic processes and resource recovery.

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