



Modeling a Coupled Hybrid Anaerobic Reactor for Generation of Energy (E2.4)

Energy and Resource Recovery Thrust



Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt)

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SUMMARY

Anaerobic reactors have the potential to transform the domestic wastewater paradigm by degrading organics from raw wastewater and concurrently producing methane (a potential source of energy). A Coupled Hybrid Anaerobic Reactor for Generation of Energy (CHARGE) is capable of treating raw wastewater to better than typical primary effluent quality and has the potential to produce a water that meets discharge standards. It has the potential to replace conventional, capital intensive, primary/secondary wastewater treatment.

The CHARGE is a simple technology that can be implemented at the front end of an existing WWTP, it has no moving parts and no energy demand when located within the hydraulic profile. The system configuration directs wastewater to the bottom of a series of sequential cells. This configuration allows for the entrapment of solids along the length of the reactor and effectively decouples the hydraulic and solids retention time, important parameters for performance. Existing anaerobic process models are simplistic and unable to represent the organic carbon and methane dynamics in a multi-cell system. A stoichiometric model is being developed based on anaerobic microbial functions in each cell. A CHARGE model that captures the essential processes needed to develop design guidance.

STUDY LOCATIONS

Plum Creek Water Reclamation Authority, Anaerobic Treatment Pilot Facility, Castle Rock, CO

I/P PARTNERS

Plum Creek Water Reclamation Authority
 Southern Nevada Water Authority

BARRIERS TO REINVENTION

- There is cultural resistance to move away from the aerobic wastewater treatment paradigms.
- There is perception that anaerobic treatment of domestic wastewater can only be successful in tropical and subtropical regions with warmer temperatures.
- There is a lack of system designs with associated performance data on mainstream anaerobic treatment technologies in temperate climates; this hinders scale-up and technology diffusion.
- There is not a modeling framework that captures the multi-compartment anaerobic reactor performance.

RESEARCH HYPOTHESES

H1: The microbial processes of a 4-compartment anaerobic reactor can be modeled via a three step anaerobic degradation pathway in which substrate is first hydrolyzed, then converted to organic acids which are then used to produce methane.

H2: The relative proportion of each microbial function will be different in each of the four compartments

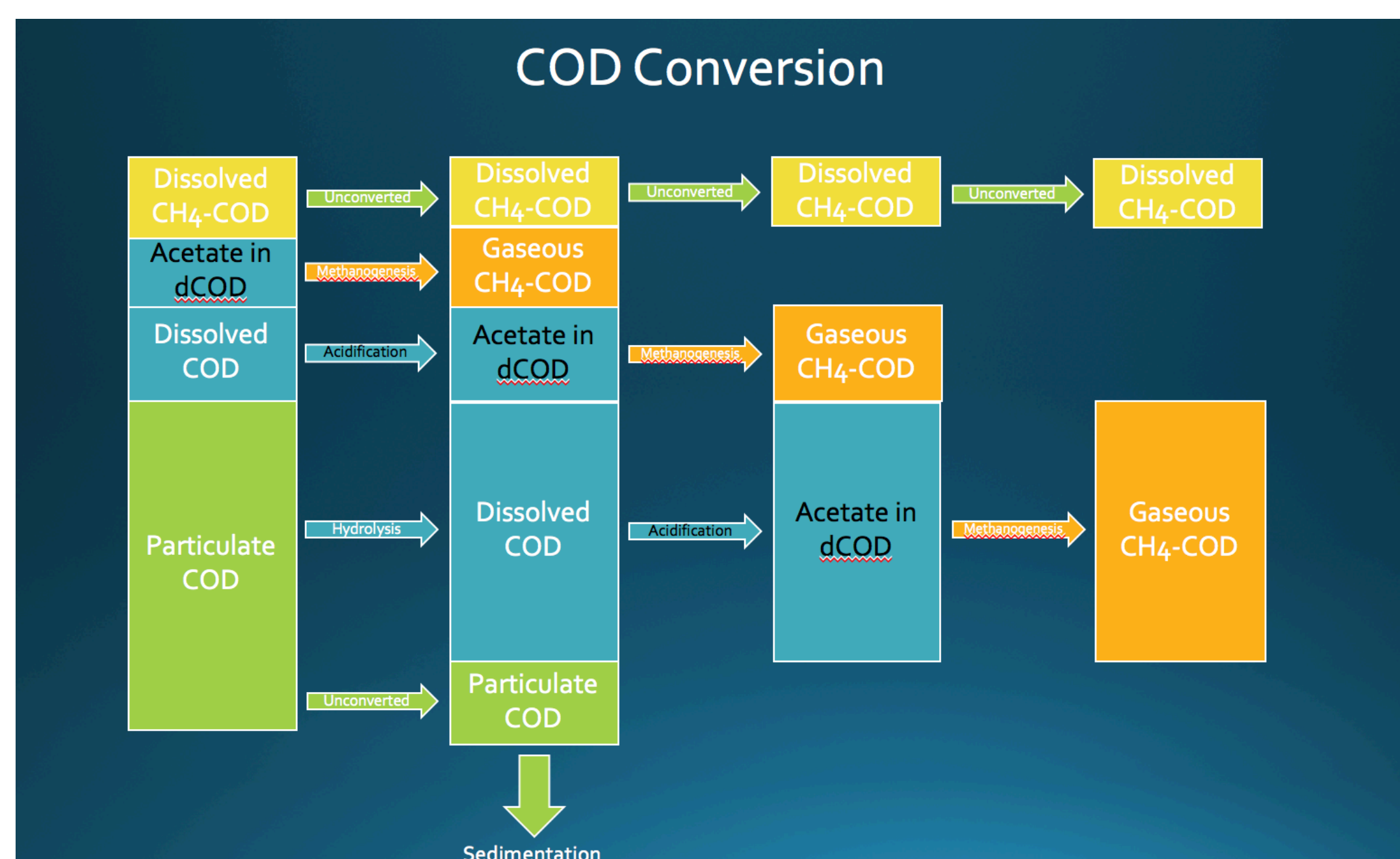


Figure 1: COD conversion pathways depicting the 3 major microbial functions: hydrolysis, acidification, and methanogenesis.

APPROACH

- Research was conducted using screened and de-gritted municipal wastewater at ambient temperatures. The pilot scale system is located in Castle Rock, CO at the Plum Creek Water Reclamation Authority.

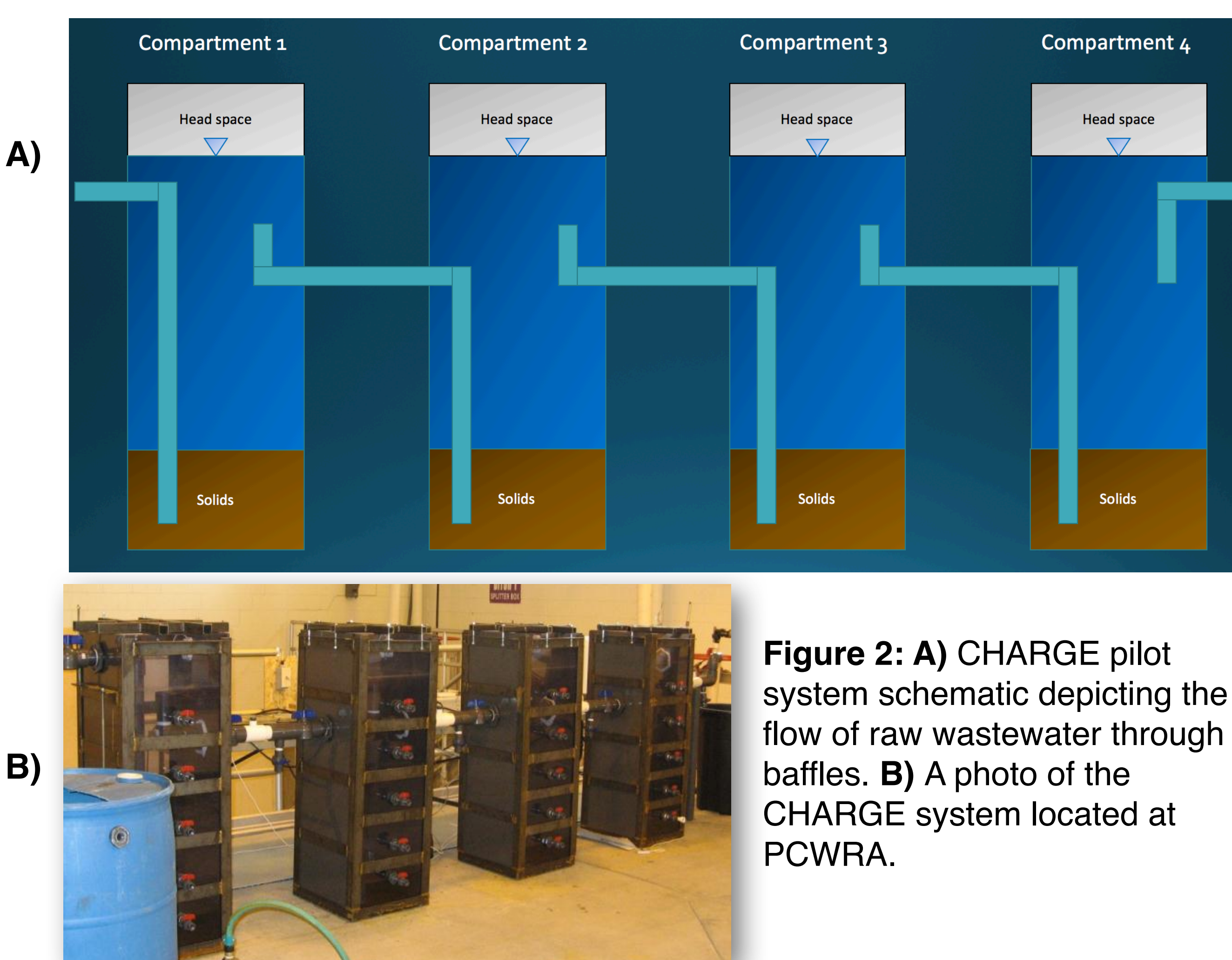


Figure 2: A) CHARGE pilot system schematic depicting the flow of raw wastewater through the baffles. B) A photo of the CHARGE system located at PCWRA.

- Data from June 2012 through August 2014 is being analyzed to lay the framework for the CHARGE model. The temperature, pH, and gas production in each of the cells were logged hourly over the duration of time being investigated. The influent water and Cells 1-4 effluent were collected weekly and analyzed for BOD, DOC, total and dissolved COD, TSS, VSS, ammonia, nitrate, nitrite, total and dissolved phosphorus, alkalinity, and individual volatile acids. Periodically, methane, iron, sulfide, oil and grease, and chloride were also analyzed.
- The organic matter transformations in each compartment were tracked by converting the input and output data into common units of COD (grams per day).
- The COD accounting was investigated for two postulated degradation stoichiometries.
- The first stoichiometry postulates that hydrolysis significantly impacts the transformation of organics, Figure 3.
- The second stoichiometry assumes that hydrolysis is not significant; therefore, it neglects the pCOD terms.

$$dCOD_{in} + dCH_4-COD_{in} = dCOD_{out} + dCH_4-COD_{out} + gCH_4-COD_{out}$$

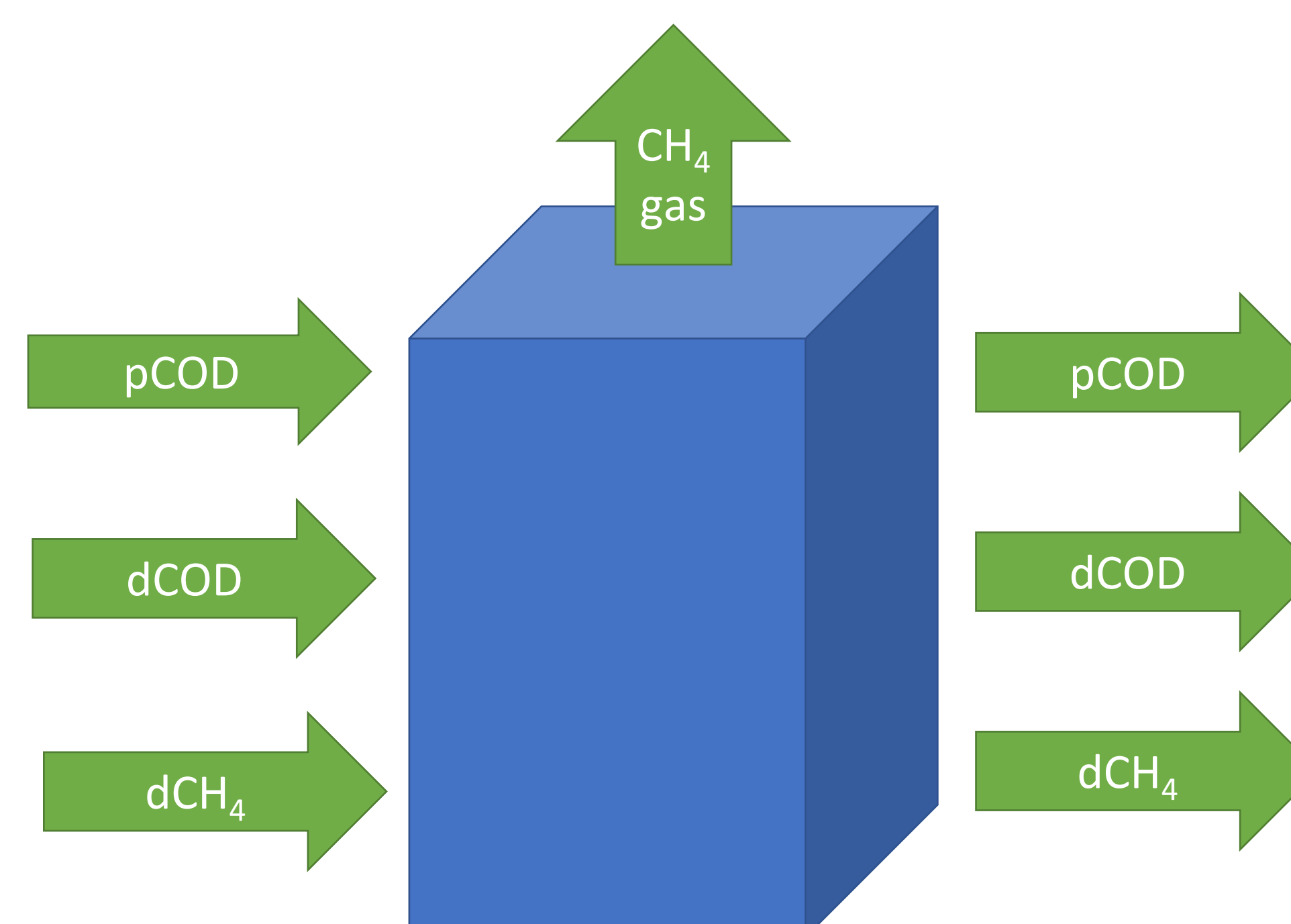


Figure 3: Mass Balance on a single compartment for pCOD to dCOD to CH₄-COD. This mass balance depicts the incorporation of hydrolysis as one of the major microbial functions.

PROGRESS TO DATE

Monthly averages were calculated for pCOD, dCOD, and methane-COD. Tables 1 and 2 present the average of the monthly averages to depict an overall COD mass balance.

Table 1: Analysis of pCOD to dCOD to CH₄ Stoichiometry

Process Location	dCOD in	pCOD in	dCH ₄ -COD in	dCOD out	pCOD out	dCH ₄ -COD out	gCH ₄ -COD out	CODin-CODout	% g COD/day difference
C1	269	1089	0	327	371	100	29	531	39.1%
C2	327	371	100	355	309	170	64	-101	-12.6%
C3	355	309	170	367	301	146	64	-44	-5.3%
C4	367	301	146	305	398	155	105	-149	-18.3%

Table 2: Analysis of dCOD to CH₄ Stoichiometry

Process Location	dCOD in	dCH ₄ -COD in	dCOD out	dCH ₄ -COD out	gCH ₄ -COD out	CODin-CODout	% g COD/day difference
C1	268.7	0.0	327.3	99.7	29.2	-187.5	-69.8%
C2	327.3	99.7	355.2	170.4	63.7	-162.2	-38.0%
C3	355.2	170.4	366.7	146.4	64.5	-51.9	-9.9%
C4	366.7	146.4	304.9	155.0	105.3	-52.2	-10.2%

The overall COD accounting using particulate COD, dissolved COD and methane COD resulted in mass balance closure to within 15% for compartments 2 and 3. The model for compartments 2 and 3 will need to include all three major microbial functions shown in Figure 1. Compartment 4 COD accounting was within 10% when only dissolved COD and methane COD were used. Thus, a model that uses the fermentation and methanogenesis microbial functions is most appropriate.

Cell 1 is the most complex cell in the system. The two postulated stoichiometries were unable to account for the change in COD observed. The 40-70% negative COD difference suggests that unaccounted for transformations exist in Compartment 1.

PLANS FOR NEXT REPORTING PERIOD

- Include COD associated with sulfate reduction and grease removal data to address the inadequate COD accounting in Compartment 1.
- Complete the stoichiometric COD analysis of Compartment 1.
- Link the stoichiometries with kinetic model for each microbial function.
- Evaluate volatile acid data to elucidate the microbial degradation pathways, to refine the models for each compartment.

RELEVANCE AND IMPLICATIONS

Successful demonstration of anaerobic treatment of domestic wastewater under psychrophilic conditions is critical to support a paradigm shift from energy-intensive aerobic treatment processes (i.e. activated sludge) to energy-positive processes. Developing a useful model that successfully describes the CHARGE performance is imperative for the future of anaerobic treatment of raw wastewater. Characterizing the kinetics in the CHARGE system has yet to be developed or well understood. CHARGE is a simple technology that can be implemented at the front end of an existing WWTP, it has no moving parts and no energy demand when located in the hydraulic profile of a WWTP. It has the potential to replace conventional, capital intensive, primary/secondary wastewater treatment.

