Wastewater research teams ↥

Another goal of this project is to generate a publishable paper recording our design and execution process including insights we've gained from analytics data. This will be done in collaboration with Nicki Dell, our faculty advisor.

Our goals are to reduce the capital cost, the operating cost, and the environmental impact of wastewater treatment. Reducing the capital cost requires decreasing the hydraulic retention time in the treatment processes. Reducing the operating costs requires elimination of aera

The long residence time required in anaerobic settled bed, UASB, reactors is likely the result of poor mass transport to the settled sludge containing the anaerobic microorganisms. Given the slow growth rate of anaerobic bacteria it is critical that the reactor design keep all of the bacteria in contact with the nutrients that must be digested.

An effective wastewater treatment reactor must be very effective at separating the retention of the solids from the hydraulic residence time. Upflow fluidized bed reactors with plate or tube settlers above the fluidized bed have the potential to have a high ratio between solids retention time and hydraulic retention time.

To bring anaerobic wastewater treatment technology to the place where it is viable for more communities in the global south we need to do the following:

- decrease hydraulic residence time
- design, invent, and test reactor geometries to obtain high reliability and minimal maintenance
- ensure that the reactor operation is stable during startup, shutdown, and flow fluctuations.
- design and fabricate a portable scale model plant that can be tested in a community using fabrication techniques that are being developed for the 1 L/s sedimentation tank.

Lessons learned for design of laboratory anaerobic reactors

- Wastewater superstocks containing the trace ingredients should be prepared to simplify preparing synthetic wastewater
- Tubing carrying tap water should enter the fridge and dilute the stock on its way to the inlet of the reactors
- Tubing carrying the synthetic wastewater to the reactor should be as short as possible
- Tubing carrying synthetic waste must have a high velocity (perhaps 0.1 m/s) to prevent sedimentation and excessive biological growth.
- Reactors in series must be closed (not open to the atmosphere) to reduce risk of overflow.
- Rising plugs can be eliminated in ASB reactors by using very low upflow velocities.
- Rising plugs in AFB reactors are a major problem that must be solved before research on AFB can proceed.
- Gas measurements based on fill and vent of a cylinder based on pressure measurements is effective, but the sensor/cylinder should be separate from the reactor

column and filled with clean water to prevent solids build up in the measurement cylinder.
- Quick connect fittings should not be used where gas tight fittings are required.

Sensor Development ↥

Skills: electronics, fluids, fabrication, ProCoDA, Mathcad. LabVIEW coding

Big questions to answer

1. How can the gas production (and hence the efficiency of the anaerobic reactors) be measured easily, continuously, and accurately?
2. How can the solids concentration in the AFB reactors be measured routinely (ideally with a turbidimeter or other continuous measurement system)?

-Tasks and goals

- Evaluate gas measurement systems, choose the best one and develop it for use by the AguaClara Wastewater teams. Ideally complete this task by the end of September so that the AFB and ASB reactors can begin using these sensors.
- Design, build, and test a fluidized bed solids concentration sensor

Gas measurement systems

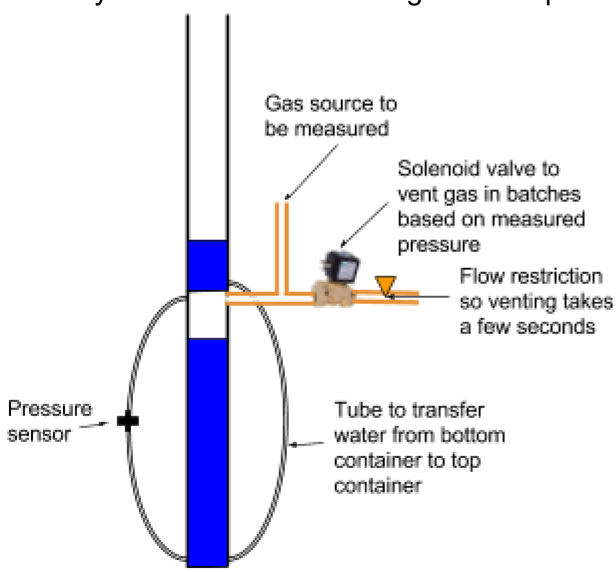
Name	How does it work	challenge
Pressure-vent using wastewater fill	Tube collects gas that displaces wastewater, pressure sensor triggers solenoid valve	Tube fills with solids (not a great option)
Pressure-vent using clean water fill	Gas is collected from reactor and transferred via tube to a sample column where the gas displaces water.	Design a two container system so that displaced water is recycled. This is the best option for the first set of sensors.
Pressure-vent using compressed gas	Gas is collected in a small tank that is full of gas and connected to a pressure sensor. Tank vents to atmosphere when pressure exceeds a target. PV=nRT. Atmospheric pressure changes will require a correction.	Will pressure fluctuations cause any problems with the wastewater reactors (not preferred due to the larger pressure fluctuations)
Methane sensor	Methane sorbs to sensor surface and changes conductivity. Advantage is	Sensor calibration was inconsistent. Further

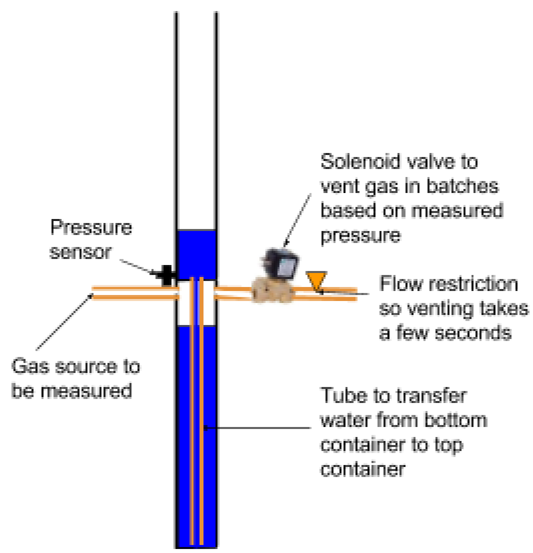
	that it measures methane rather than total biogas. Disadvantage is requires a pump.	testing required to determine if the sensors are reliable

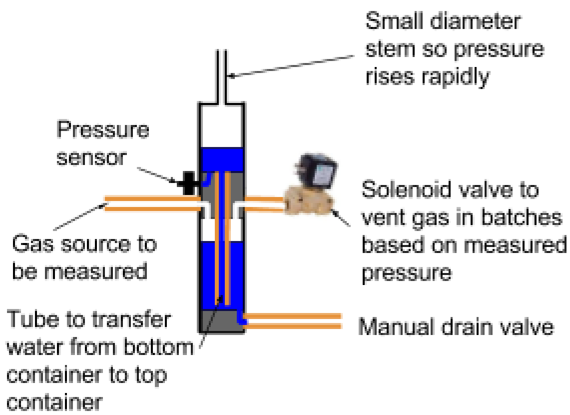
Below are three sketches of the pressure-vent using clean water fill.The 3 sketches show a design progression that simplifies plumbing, shortens the reactor height, and increases the precision of triggering the gas release. The 3rd design can rely on time to exit the vent state rather than on pressure because the upper chamber can empty completely. Thus the solenoid valve can open and stay open for a fixed amount of time. This will improve the accuracy of the volume measurement. An ideal gas measurement device will only create a few cm of back pressure and thus the distance between the bottom of the bottom chamber and the top of the top chamber should be limited to 5 cm if possible.

The volume of gas measured in a single cycle should be much larger than any single gas release events (burbs) from a ASB reactor. ProCoDA response time for triggering opening of the vent valve is a function of how much data averaging is required. It is likely that 100 ms of data (25 data points at 2.5 kHz) is sufficient to get a good pressure measurement from the pressure sensor. The vent time must be small (perhaps 1%) of the fill time so that gas lost during venting is insignificant. The sensor software could correct for this loss. The vent time is controlled by the head loss of the water flow from the upper chamber to the lower chamber.

It may be reasonable to vent gas as frequently as several times per minute.







The sensor system will require software to connect the sensor to ProCoDA. The gas sensor software will be a state machine that automatically cycles between fill and vent states. This state machine will be written to be an external code that can be linked to ProCoDA.

External code that connects with ProCoDA can have multiple inputs, but only one output. The sensor system will require an output to control the solenoid valve and a second output that calculates gas production in moles or volume at standard temperature and pressure. Given that each piece of code can only have one output, this can be accomplished by creating two separate pieces of external code. The first code controls the vent valve and will take the inputs of

- pressure sensor
- vent time
- trigger pressure given as change in pressure between empty and full

The output will be either a zero or one to control the solenoid valve

The second code is the gas volume meter and will take the inputs of

- Solenoid valve control (output of the first code)
- Temperature
- Sample cell volume per cycle in mL
- vent time
- Reset state (a state ID number that will cause this code to reset the totalizer for gas production)

The gas volume meter will correct gas production (based on the time between venting events and the vent time) for the time spent venting. The output will update when the vent valve control changes to a 1. The output could be either total moles of gas or volume at standard temperature and pressure.