Anaerobic Wastewater Treatment

Location: HLS 150
Skills: biology, wastewater, lab experience, culturing, Process Controller

Major findings in summer 2013

- plugs of granules rise with biogas binding - is this a function of small diameter pipe or inherent to the nature of the sludge (that it will rise on occasion); could agitation help minimize rising sludge?
- If using sand as an inert growth surface, need to calculate estimates for surface area of sand required to hold biofilm needed to convert organics to methane
- serum bottle tests can be used for testing activity of different sludges (or the same reactors' sludge over time)
- In UASB mode, Granules from a brewery wastewater were unstable, have poor settling characteristics and become buoyant from the biogas
- Gas/Liquid/Solid separation is difficult with conventional UASB design. The tube settler design is slightly improved but doesn't solve the inherent problems with unfluidized beds producing buoyant gas bound granules
- Biogas capture seems low based on amount of COD destroyed/lost in reactor: leaks? O_2 fluxing in and leading to aerobic processes stealing COD from the anaerobes?

Goals

The objective of this research is to develop a robust, sustainable, low energy, operator friendly, wastewater treatment system. The expectation is that wastewater treatment technologies have failed to evolve and optimize due to the same influences that caused drinking water treatment technologies to stagnate. Our goal is to bring the insight of biological aspects of waste conversion, fundamental mechanisms, limitations of mass transfer, understanding of the interactions between reactor geometry and the fluid dynamics of multiphase flow to this task so that we can create a much improved anaerobic digester.

Full scale UASBs have problems with clogging of the influent pipes. This is consistent with the flat bottom geometry of the UASB that causes flocs to accumulate, form sludge and eventually cause an avalanche unto the inlet pipe and block the flow. UASBs don't seem to have a method to manage sludge accumulation. It seems that solids accumulate in the bottom of the reactor and leave the reactor in the effluent. The lack of a proper sedimentation design for the effluent could result in high effluent suspended solids concentration. Visit the glass walled AguaClara sedimentation tank apparatus in HLS 160 to learn how flocs are recycled in a fluidized bed system.

The time scale for anaerobic biological processes is relatively long due to the low yield and slow growth of anaerobes. To accommodate this slow process it will be necessary to conduct experiments in parallel rather than in series. Thus the experimental apparatus needs to be designed to handle multiple setups. Ideally a single computer should be able to control a set of reactors. Determine what constraint controls how many reactors a computer can control and design and construct multiple reactors.

Fluid shear is expected to be a significant parameter determining the viability of fluidized bed reactors. Develop the equations for surface shear on the particles in a fluidized bed and evaluate the effect of media size and density on surface shear.

Sedimentation velocity of the media is a function of density and density is a function of the thickness of the biofilm layer. Derive the equations to model the sedimentation velocity of a sand grain as a function of the sand grain diameter and the thickness of the biofilm. Determine if biofilm growth will send sand grains to the bottom of the reactor or to the top of the fluidized bed. Determine if this result is a function of the density and diameter of the original media.

Create a set of hypotheses that might explain why the hydraulic residence time is generally so long in anaerobic digesters. Note that the residence time in traditional water treatment plants was approximately 5 hours and that AguaClara has reduced that by about a factor of 10. Thus there is reason to expect that a well designed anaerobic digester could be much higher rate than conventional design.

Calculate how much active biomass is needed and hence estimate the required surface area of biomass on the fluidized bed media.

Specific tasks for team: Help with construction, maintenance, and troubleshooting of multiple reactors.

- Construction of several new tube settler reactors (probably 5)
- Feeding the reactor (using 20x stock)
- Collecting and analysis of biogas production data and turbidity
- COD tests on influent and effluent water.
- Microscopy

Compare reactor operation, performance, start-up, etc. by varying the density and size of different support media. Ideally, five different reactors could be run in parallel (same HRT, organic loading rate, recycle ratio) while varying only one parameter, for example the support medium density. Replicate reactors can be run in parallel, this would requires construction of more reactors. Other parameters could also be experimented with such as HRT, waste "strength" etc.

Research questions...

1. Compare performance of UASB using different media diameters and densities. Also consider Anaerobic Fluidized Bed Reactors (AFBRs) such as used in paper: Kim et al "Anaerobic Fluidized Bed Membrane Bioreactor for Wastewater Treatment" ES&T 2011 Volume 45, 576–581.
2. Can UASB/AFBR effluent be treated (or process redesigned) as to remove fecal bacteria better?? Is there any benefit in adding

low dosages of coagulant to enhance flocculation of colloids in the UASB/AFBR?
3. Are effluent turbidity measurements useful/important?
4. What is the minimum upflow velocity that is compatible with a fluidized bed and that can achieve good solid/liquid/gas separation? Explore media diameter and density.
5. Can we model the processes (adopt mechanistic models from the literature to our configurations)

Hypothesis to test

- Hydraulic retention time in anaerobic digesters must be long enough so that the minimum cell residence time required for the anaerobes can be maintained. Improving efficiency of biomass capture/retention will allow a decrease in HRT. It is possible that a well designed reactor could have a very short HRT.
- Biomass retention can be improved by adding support media that has a higher density than the biomass.
- Fixed bed reactors could also be used to increase solids residence time and provide protection against washout during a high flow event.
- Stacked rapid sand filtration or SRSF could be used to capture solids and the backwash water would be returned to the digester (This will require pumps)
- An anaerobic fluidized bed reactor with a low density fluidized bed media such as activated carbon or sand would allow higher upflow velocities and thus potentially a smaller reactor footprint than a UASB. The size and density of the media used to create the fluidized bed are critical. Shear on the surface of the granules is a function of density and diameter. The maximum surface area per unit volume of the reactor increases as the diameter of the granules decreases and the density increases. So if anthracite is good, then small sand grains might be even better.
- If upflow velocities required for AFBR are so high that reasonable height reactors will only have a HRT of a few minutes and if a longer HRT is needed, then a series of AFBR reactors could be used to eliminate the need for recycle.