Upflow Anaerobic Sludge Blanket Reactors

The fabrication of small-scale packed bed UASB reactors.
More information can be found on the AguaClara wiki page - (UASB)

Wastewater Around the World

- "Up to 90% of wastewater in developing countries does not undergo treatment" [1]

- Environmental and health hazard

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Current State of Treatment

High capital/operating costs and large energy demand

not feasible in rural and impoversihed regions due to high cost and inability to treat low flows

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Our Goal

Develop low cost, low energy, small scale wastewater treatment

Overview of UASB Technology

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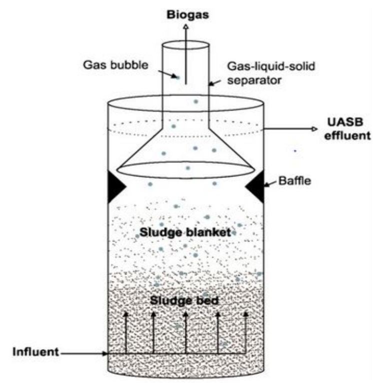


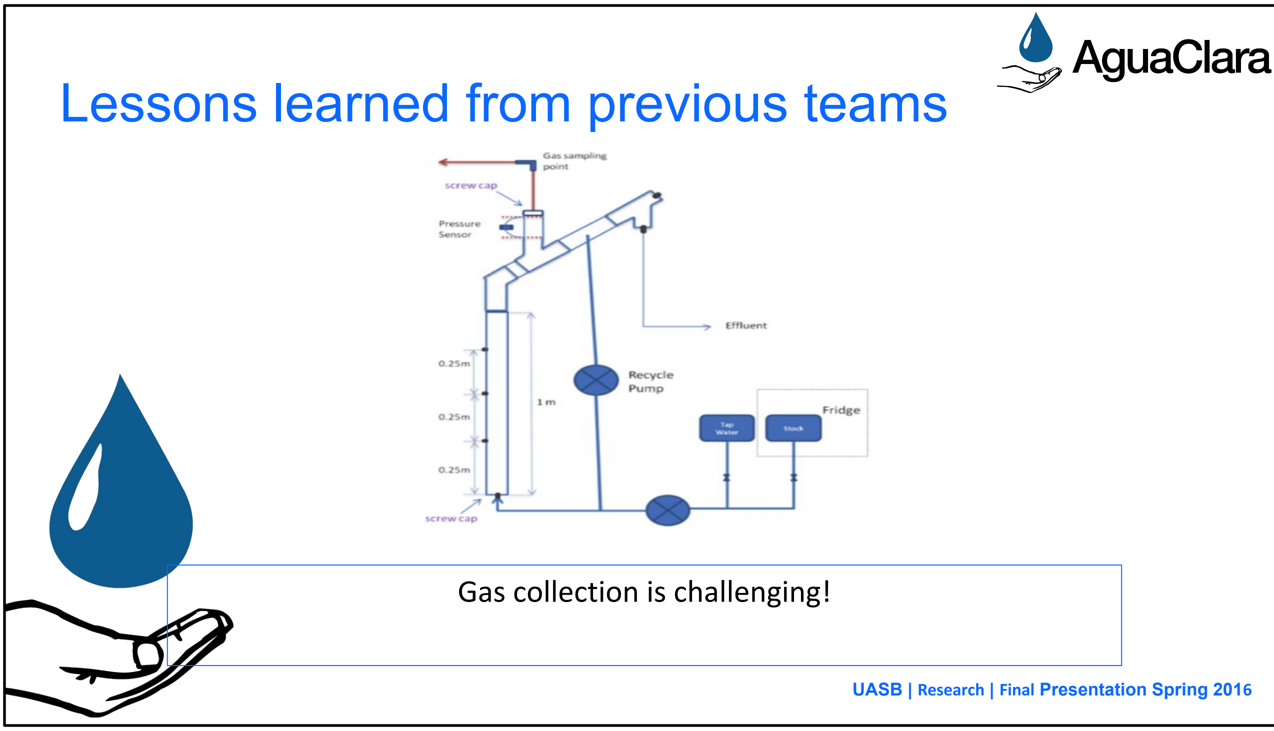
(Chong et al. 2012)

The Upflow Anaerobic Sludge Blanket Reactor

- influent wastewater contains chemical oxygen demand (COD)

- granular biomass of a mixture of bacterial species form a sludge bed and fluidized sludge blanket
- granules process the COD to produce **<u>biogas</u>** (Methane and Carbon Dioxide)

- biogas is captured by Gas-Liquid-Solid (GLS) separator



Summer 2013: Challenges: Poor treatment efficacy

- ➢ Biomass washout, granular disintegration, scaling

Fall 2013: Challenges: inability to collect significant data for gas production

- ➢ Leaks, lengthy startup time

Spring 2014: Challenges: inconsistencies between theoretical and experimental gas production, inconsistent COD feed concentration delivery, and vessel leakage

Fall 2015: Challenges: inability to collect significant data for gas production

- ➢ Leaks, lengthy startup time

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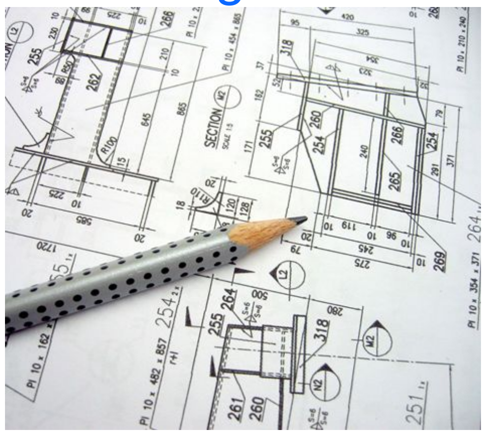
Focus of This Semester

Building a set of small-scale reactors

Moving from spacious teaching lab to the more snug AguaClara lab imposed some size limitations.
Previous large reactors were unstable and broken after falling over.
New reactors were designed to better suit the lab space.
This gave us the opportunity to redesign the reactors to eliminate inefficiencies and issues caused by the old design.

MathCad Reactor Design



4 hr HRT. Upflow velocity 0.05 mm/s

Constraint: HRT fixed at 4 hrs and upflow velocity at 0.05 mm/s

Performed all calculations for Sch40 PVC from 0.5” id to 3.5” to determine the optimum inner diameter

Reactor height required calculated based on constraints HRT*Vup - 2.36 ft

Calculated reactor volumes

Calculated flow rates required for water and influent wastewater to deliver necessary 3gm/L/day COD loading

Determined that for our system, with the bench space and pumps available that 1” is optimum diameter

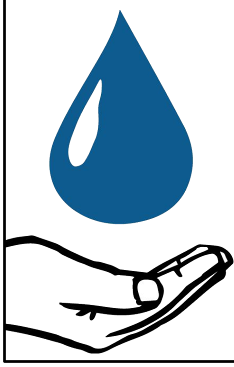
Design Process

- The team had very little fabrication experience, so training was needed. Threading, sanding, cutting, glueing
- 4 identical reactors

- Minimize number of ports into and out of reactor to maintain air-tightness

- Head unit
  - Option for methane sensors for gas production quantification
  - Narrow head unit for more frequent offgasses with old methane sensing method

Benefits of New Design



- Properly sized for the new lab space
    - Easily secured to lab bench

- Simplified inoculation and maintenance with new design

- Skills gained from fabrication

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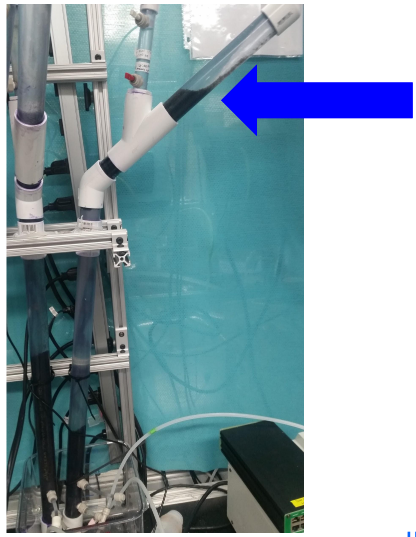
Drawbacks of New Design



- Rising plugs of granules- Air cannot navigate through the densely packed granules and causes plugs of them to rise up the body of the reactor. The narrow body of the reactor provides too much drag and overpowers the force of gravity

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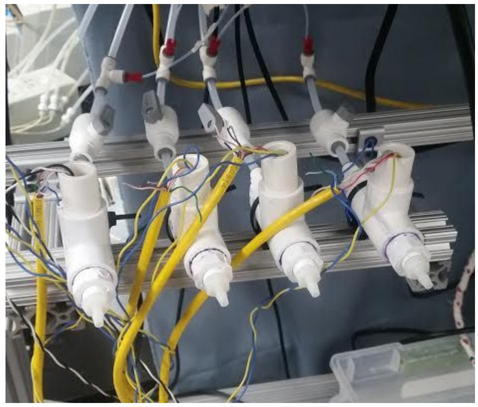
Drawbacks of New Design

- ➢ Daily maintenance- need to change influent and effluent tanks every 18 hours

- ➢ Cluttered lab space

Future Improvements



Gas Collection!

- Efficient use of pumps
- Reduced daily maintenance
- Obstructions to breakup plugs

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Future Work

Gas Collection and Experimentation!

- Reactors will used for research over the summer
- Analyze effect of oxygen stress on culture resiliency, methane production, and COD treatment efficiency
- Analyze the biomass response to a variable influent COD concentration and highly concentrated blackwater

Questions and Recommendations

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Thank You

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Appendix Slides

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References

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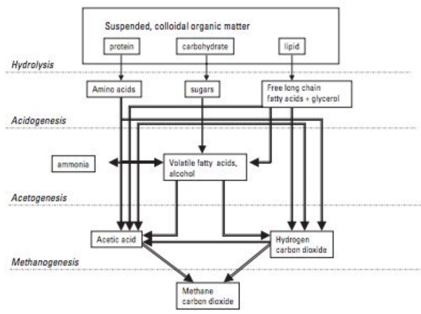
COD Processing Within Granules



(Mes et. al 2003)

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Mathcad Design

$$Reactor_{Height} := V_{UpReactor} \cdot HRT_{Reactor} = 2.362 \cdot ft$$

Determine reactor height based on upflow velocity and hydraulic retention time

$$V_{LRreactor}(H_{LR}, D_{LR}) := \pi \cdot \frac{D_{LR}^{2}}{4} \cdot H_{LR}$$

Reactor Volume Equation

$$D_{LR} := \begin{pmatrix} .602 \\ .804 \\ 1.029 \\ 1.36 \\ 1.59 \\ 2.047 \\ 2.455 \\ 3.042 \\ 3.521 \end{pmatrix} in$$

Diameter of Sch40 PVC available

$$Q_{Required} := Q_{Check}(HRT_{Reactor}, V_{LRctrCheck}) = \begin{pmatrix} 0.551 \\ 0.983 \\ 1.61 \\ 2.812 \\ 3.843 \\ 6.37 \\ 9.162 \\ 14.067 \\ 18.846 \end{pmatrix} \cdot \frac{mL}{min}$$

REQUIRED reactor inlet flow rates to maintain the HRT and Vup

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Mathcad Design

$$M_{Daily}(OLR_{value}, V_{Rctr}) := OLR_{value} \cdot V_{Rctr}$$

grams/day COD influent required to meet Organic Loading Rate of 3 gm/L*day

$$C_{Influent}(Q_{Influent}, M_{Flow}) := \frac{M_{Flow}}{Q_{Influent}}$$

$$Q_{StockCalc} := Q_{Stock}\left(Q_{Required}, \frac{C_{ConcentratedStock}}{C_{InfluentCalc}}\right) = \begin{pmatrix} 0.055 \\ 0.098 \\ 0.161 \\ 0.281 \\ 0.384 \\ 0.637 \\ 0.916 \\ 1.407 \\ 1.885 \end{pmatrix} \cdot \frac{mL}{min}$$

For size 13 peristaltic tubing, the pump can go down to 0.1 mL/min. This limit is at a reactor diameter of 1"

$$Q_{Water} := 5\frac{mL}{min} - Q_{StockCalc} = \begin{pmatrix} 4.945 \\ 4.902 \\ 4.839 \\ 4.719 \\ 4.616 \\ 4.363 \\ 4.084 \\ 3.593 \\ 3.115 \end{pmatrix} \frac{mL}{min}$$

Flow Rate Influent Water

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