OLD REPORT AguaClara Wastewater Granular Sequencing Batch Reactor (GSBR) Spring 2016 Research Report

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Abstract

Briefly summarize your previous work, goals and objectives, what you have accomplished, and future work. (100 words max) If you have a question, please use the help menu ("?") on the top bar to search for help or ask us a question.

Introduction

Explain how your completion of your challenge will affect AguaClara and our mission of providing safe drinking water (or sustainable wastewater treatment!). If this is a continuing team, how will your contribution build upon previous research? What needs to be further discovered or defined? If this is a new team, what prompted the inclusion of this team?

Literature Review

Discuss what is already known about your research area. Connect your objectives with what is already known and explain what additional contribution you intend to make. Make sure to add APA formatted in-text citations like this (Tennekes and Lumley, 1972). If you mention the author(s) in your sentence, you can simply give the year of publication. For example, Tennekes and Lumley (1972) wrote an excellent book on turbulence.

Beun, M.C.M. van Loosdrecht, and Heijnen compared the granule formation in an intermittently fed sequencing batch airlift reactor (SBAR) and a continuously fed biofilm airlift suspension reactor (BASR) ultimately concluding that the SBAR was more efficient. The most striking difference was the density of the granules in which the density of the granules produced by the SBAR was as high as 60 g VSS/l granules whereas the density of the granules in the BASR was only as high as 20 g VSS/l granules. Feeding the substrate intermittently allows for higher acetate concentration and acetate penetration up to $500 M$M in the SBAR compared to less than 20 MM in the BASR. Therefore, the BASR cells in the center of the biofilm are deprived of acetate, which leads to a lower biomass density of the granules and a porous structure. Greater detachment

forces due to high bare carrier concentration in the BASR also led to a decrease in granule density. Additionally, the SBAR had a shorter settling time since granules developed within 1 week after inoculation. Granular sludge with a settling velocity greater than 10 m/h was then separated from the biomass mixture.

He-Long Jiang, Joo-Hwa Tay, Yu Liu and Stephen Tiong-Lee Tay (2002) examined the influence of calcium on the granulation in the sequencing batch reactors. Experiments were conducted on 2 reactors R1 and R2. Reactor R1 had no Calcium added in it while R2 had 100 mg/L of Calcium concentration. After 2 months of study, it was concluded that 100 mg/L calcium augmentation reduced the time required for granules to grow in the reactor from 32 days to 16 days. Along with a reduction in time required for growth; it was also found that adding calcium helped in forming denser granules. Addition of calcium also increased COD removal (5% more as compared to reactor with no Ca augmentation). On average the size of biomass in R2 was greater than that of R1, and extracellular polysaccharides in R2 were found to be twice of those in R1.

Previous Work

Discuss what is already known about your research area. Connect your objectives with what is already known and explain what additional contribution you intend to make. Make sure to add APA formatted in text citations.

Since the spring of 2014, the AguaClara wastewater team has conducted research on aerobic granular sequencing batch reactors. This was originally initiated by a realization of the need for additional polishing following anaerobic treatment (i.e. upflow anaerobic sludge blanket technology) due to the promise of lower cost aerobic treatment that GSBRs had shown in literature as well as nutrient removal capabilities. From the spring of 2014 to 2016 there have been several GSBR reactors inoculated and tested by AguaClara researchers as well as visiting students from Brazil.

In the summer of 2015, two Brazilian students, Maria Dias and Mirelly Manica, began an experiment to look into the the removal efficiencies GSBRs under both low and high airflow rates. The team successfully created granules, albeit small in diameter but in large concentrations. The team arrived at important conclusions regarding the performance of GSBRs. Although consistent in its high COD removal efficiency, at above 80% for all but one of the sample dates, the GSBR monitored over the summer showed limited phosphorus and nitrogen removal. The reactor achieved a minimum of 19% phosphorus removal efficiency, with a maximum below 60%. Additionally, the GSBR satisfactorily achieved nitrification, as the ammonium concentration decreased dramatically over the course of the cycle. However, denitrification was weak as nitrite/nitrate concentrations were elevated in the effluent and rarely showed any signs of removal (cite 2015 summer report).

In the fall of 2015 research under AguaClara continued into the nitrogen removal capabilities of one GSBR inoculated by Maria Dias and Mirelly Manica. The goal for the semester was to improve denitrification by imposing a new aeration schedule that would limit dissolved oxygen in the reactors in the second half of the aeration phase. The intention was to allow more denitrifi-

cation to occur inside the anaerobic cores of the granules under lower oxygen concentrations. Through the semester research, however, it was demonstrated that the lack of aeration reduced nitrifcation in the GSBRs and thus limited the reactor's overall nitrogen removal. Nonetheless, through the semester high COD removal was still recorded with the lower aeration rate. Lastly, another finding came with the long-term decrease in the granule structure for the GSBR biomass. Due to the limited airflow and hydraulic shear, the granules began to deteriorate and become less compact. Further research into GSBRs would be wise to utilize sufficient airflow for granule stability.

Methods

Explain the techniques you have used to acquire additional data and insights. The techniques should be described in sufficient detail so that another researcher could duplicate your work.

Analysis

Connect your work to fundamental physics/chemistry/statics/fluid mechanics or whatever field is appropriate. Analyze your results and compare with theoretical expectations or if you have not yet done the experiments, describe your expectations based on established knowledge. Include implications of your results. How will your results influence the design of AguaClara plants? If possible provide clear recommendations for design changes that should be adopted. Show your experimental data in a professional way. Refer to Grammar Guidelines for Reports for details on formatting. Be sure to reference figures before they appear in your paper (see Figure 1). Be sure to do the same for tables (see Table 1).

Figure 1: Captions go beneath figures.

Table 1: Captions go above tables.

Parameter	Symbol	Value
Residence Time	θ	90 s
Hydraulic Gradient	G	500 s^{-1}

Conclusions

Explain what you have learned and how that influences your next steps. Make sure that you defend your conclusions. (this is conclusions, not opinions!)

In the results section, present a summary of your results in a professional way and then analyze these results. When analyzing results, think about how the results support or do not support your original hypotheses and motivation to run the experiment. The following are guiding questions to assist you in writing this section:

- What results do you get from the data?
- Does the data support your hypothesis? Why does it support or not support it?
- Are there new insights that you get from this data?

- If the data does not support your hypothesis, is there another hypothesis that describes your new data?

Future Work

Describe your plan of action for the next several weeks of research.

References

Tennekes, H. and Lumley, J. (1972). *A First Course in Turbulence.* MIT Press, Cambridge, Mass.

Semester Schedule

Task Map

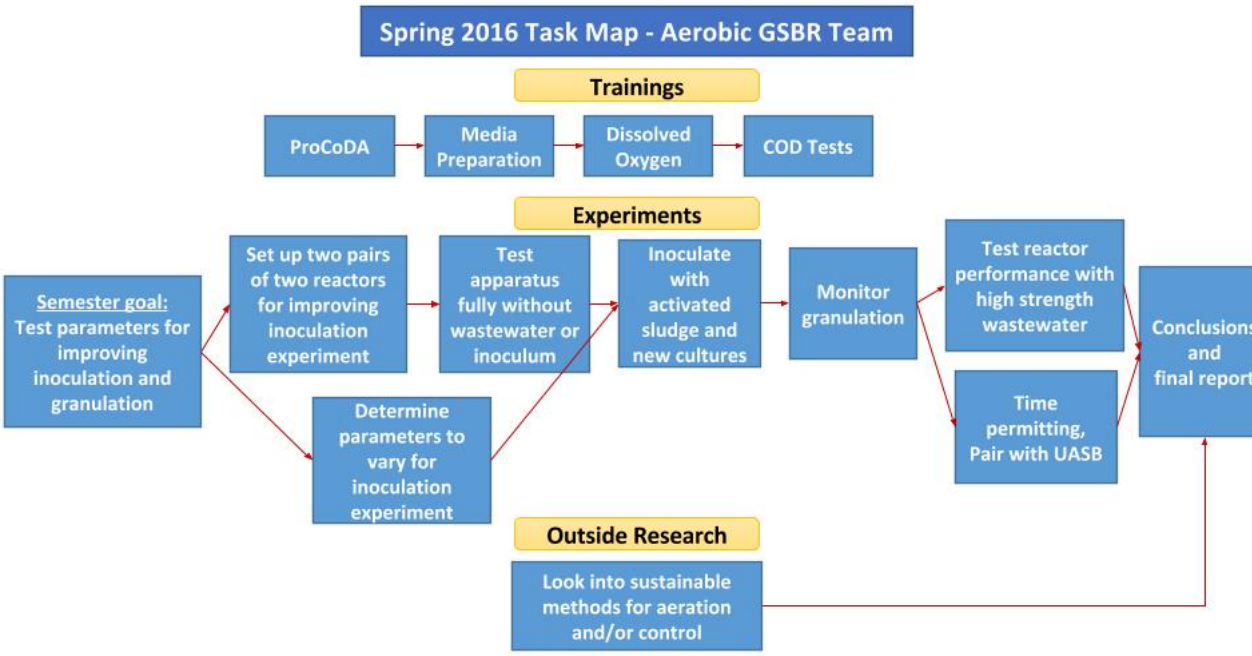

Figure 2: Task Map for Spring 2016

Task List

Goals for this semester include conducting an experiment on improving inoculation and granulation by testing two sets of two reactors with varying parameters, followed by testing the effects of high strength wastewater on GSBRs, and possibly pairing GSBRs with UASB effluent. In addition, low-tech aeration and control methods will be explored through literature and non-laboratory research. For each task, a team member is assigned as the lead, which means the team member assumes responsibility for coordinating and delivering the task.

1. **Group training**
   These tasks include training events intended to teach all team members essential laboratory methods that will be used throughout the semester. These training events may be conducted with other AguaClara wastewater teams.

   (a) ProCoDA (2/24/16) - Amiel

   (b) Dissolved oxygen measurement (2/29/16) - Amiel

   (c) Media preparation (3/2/16) - Nisarg

(d) COD analysis (3/14/16) - Amiel

(e) Nitrogen and phosphorous assays (*TBD if needed*)

2. **Setup and start-up of four new GSBR reactors**
The first task for our semester will be to setup and begin operation on four new GSBR reactors. The goal is to test the the improvement of the inoculation and granulation phase in GSBRs through an experiment operating two sets of two new reactors. This set of tasks includes setting up the physical apparatus for the new reactors as well as programming a new ProCoDA control program. This will also include a full test of the reactor system without wastewater or bacteria.

   (a) Create full process schematic for four reactors (2/19/16) - Amiel

   (b) Create list of necessary equipment and materials (2/19/16) - Victoria

   (c) Setup pumps and plumbing (02/22/16)- Victoria

   (d) Setup accumulator(s) for aeration (02/24/16) - Amiel

   (e) Program control with ProCoDA (02/26/16) - Amiel

   (f) Setup fridge and stock tanks (02/25/16) - Victoria

   (g) Run the reactor for a cycle with tap water (02/29/16) - Nisarg

   (h) Gas transfer test of aeration system (03/02/16) - Nisarg

   (i) Retrieve the bacteria to inoculate (03/11/16) - Amiel

   (j) Start the reactors (03/11/16) - Amiel

   (k) Monitor performance - All

3. **Determine parameters to vary for inoculation experiment**
The major goal for the semester will be to find new ways to improve the inoculation and granulation phase for GSBRs. To do this, one to two parameters will be varied between the two sets of reactors. Before conducting this experiment the parameters to be varied must be determined. At the start of the semester, the parameters considered include type of inoculum (sources for mixed-cultures), aeration rate, and type of substrates. These tasks will be conducted concurrently with the setup of the new reactors.

   (a) Review literature to for these three parameters influence on granulation (2/17/16) - All

   (b) Consult with Ruth and Cristina (2/17/16) - All

   (c) Make final decision (2/22/16) - Amiel

4. **Research new dissolved oxygen probes for lab**
The dissolved oxygen (DO) probes that are currently available to AguaClara require constant maintenance and provide fairly noisy results. For this reason, research will be conducted into finding new DO probes that are more reliable and more accurate.

   (a) Research online manufacturers for new DO probes (2/19/16) - Nisarg

   (b) Calculate and compare costs of 3-4 options (2/22/16) - Victoria

   (c) Review findings with Monroe and purchase (2/24/16) - Nisarg

5. **Test reactor performance with high strength wastewater**
   AguaClara's research into GSBRs has thus far used wastewater with a COD of about 500 mg/L. One goal for this semester is to increase the strength of the wastewater used to ideally match that of blackwater. This will be done after operating the reactor with normal strength wastewater (COD of 500 mg/L) for at minimum several weeks. Test may include either several short spikes of high strength waste or may cover a longer time.

   (a) Pick high strength wastewater composition (4/22/16) - Victoria

   (b) Run experiment by feeding high strength wastewater to one set of two reactors (4/25/16) - All

   (c) Monitor results - All

6. **Look into low-tech aeration and/or control methods**
   One interest of the AguaClara GSBR team is in the viability of GSBRs as an application in Honduras. Sustainable and affordable aeration and control mechanisms would need to be used in order to operate a potential GSBR with low-energy usage. Possibilities for further research will be explored over the semester along with recommendations for future experiments.

   (a) Conduct research on low-electricity methods for aerating the reactor (4/6/16) - Nisarg

   (b) Conceive low-tech options for control of reactor (4/20/16) - Amiel

   (c) Estimate net electricity consumption of the reactor (4/27/16) - Victoria

7. **Research Reports**
   The team member in charge of a research report is responsible for the final review and submission. All team members are expected to contribute equally to each report.

   (a) Research report due 2/26/16 - Nisarg

   (b) Research report due 3/11/16 - Amiel

   (c) Research report due 4/8/16 - Victoria

   (d) Research report due 4/22/16 - Nisarg

   (e) Final Report draft due 5/11/16 - Amiel

   (f) Final Report due 5/18/16 - All

8. **Conclusions and analysis**

   (a) Review data on inoculation experiment as well as high strength wastewater test (5/1/16) - Amiel

   (b) Draw conclusions and suggest future work (5/9/16) - All