AguaClara Program Challenges
Fall 2017

This fall we have a major effort to go full open source by switching to Python for the majority of our coding including the Aguaclara Infrastructure Design Engine. Marketing, knowledge management, and finance are increasingly important as the program grows and becomes truly multidisciplinary and multinational. AguaClara projects are expanding in 3 countries (Honduras, India, Nicaragua), we are expanding the range of flow rates that our plants can treat, and we continue to develop improved understandings and designs of the treatment processes.

AguaClara is developing new insights into the core process of flocculation and those new insights lead to a whole new set of research questions. No one has ever optimized the design of a surface water treatment plant before and thus there are many opportunities for significant advances. We are conducting the research to get us closer! Along the path to optimization we may make some very cool discoveries.

Team (with link to wiki)	link	Adviser	#	Location	#
Going Global Teams					
Public Relations	↓		3	B63	1
Webmasters and Knowledge Management			3	B63	2
Investments Team (CEE 2550 only)	↓	John Foote	3	B63	3
Apps and Algorithms Teams					
AIDE: AguaClara Infrastructure Design Engine	↓	Daisy Fan	9	B63	4
POST: apps for plant operators and data analysis	↓		4	B63	5
Floc size and count app	↓		3	B63	6
Wastewater Research Teams					
Anaerobic Settled Bed (UASB) (EPA phase I)	↓	Ruth Richardson	3	1	7

Water Quality Monitoring for Diarrheal Pathogens	⤓	Ruth Richardson	3	2	8
Particle Removal Research Teams					
Contact chamber	⤓		3	3	9
High G Flocculation	⤓		3	4	10
High Rate Sedimentation (HRS)	⤓		3	5	11
Filter Constrictions	⤓		3	6	12
StaRS Filtration Theory	⤓		3	7	13
StaRS outlet slotted pipe upgrade	⤓		3	8	14
1 L/s plant testing	⤓		3	DeFrees	15
Dissolved Species Removal Research Teams					
Fluoride (EPA P3 Phase II grant)	⤓		3	9	16
Humic acid, kaolin, floc/sed model	⤓		3	10	17
Two Stage Coagulant Addition	⤓		3	11	18
Fabrication and Physics Teams					
Ram Pump	⤓		3	12	19
Sensor Development (Fluidized bed solids concentration (lab and field))	⤓		3	Isla	20
Flow control for modular Enclosed Stacked Rapid Sand (EStaRS) Filters	⤓		3	Isla	21
Total (20 teams)			69		

Opportunities for technical writing credit (by permission of instructor)

- Website content update
- EPA phase 1 proposal (topic TBD)
- final report for HRS must be submitted to EPA by 12/31/2017

Additional opportunities

- Opportunity for molecular modeling research in Dr. Aristilde's lab
- Create a water quality monitoring team to develop methods to measure a wider range of surface water quality parameters during the Honduras trip including pathogen detection.

Going Global Teams

Public Relations ↥ CEE 2550 only

Skills: Writing, graphical design, networking

Tasks and goals

1. Social Media, Website, Newsletter
    - Communications Major

    a) Use Social Media platforms: Instagram, Facebook, Twitter

    · Spreading the word, fundraising

    c) Update/develop Website Content

2. Poster Development and Presentations
    - Communications, Business?

    a) Trifold for team member recruitment
    - Organize folders of templates and stock photos for posters

    b) Potentially create presentations for speaking events

3. Branding

    a) Create Brand book

    b) Logo

4. Video

    a) Marketing AguaClara Technologies
    - Honduras trip
    - Video of Lab
    - Make video of how water flows through plant and link it to the aguaclara.cornell.edu website

5. Organize an alumni reunion for June of 2018 (coordinate this with Alissa Diminich)

Webmasters and Knowledge Management ↥

Skills: web design

Tasks and goals

AguaClara.cee.cornell.edu

1. Add a DONATE button!

2. Update content in collaboration with the PR team
3. Fix broken, missing links
4. Provide more rapidly changing content from current projects
5. Timeline - update
    a. Dates of plant construction
    b. Dates of newly implemented technology
    c. Other notable events
    d. Add photos
6. Technology Pages
    a. Contains a higher level description of how the technology works
    b. Tells the story of how the technology developed
    c. Contains links to the current pages of the unit processes
7. AguaClara International Map
    a. See wiki projects page for info on how to edit map
    b. Add sites in India
    c. Update sites in Honduras and Nicaragua

Wiki and Knowledge Management Upgrade

AguaClara has developed a large collection of knowledge and we do not have good methods of transmitting (or making available) that knowledge to new team members. The result is that significant time is lost due to students missing key pieces of information that were previously known, but that weren't passed along to new students. A recent example of this is that PACl stock solutions must be prepared using reverse osmosis water (not tap water) to prevent precipitation of the PACl in the stock tank. This information was lost and teams didn't realize that this was important. This challenge is to review how the AguaClara program manages knowledge and to propose improved methods to make that knowledge more easily accessed.

Ensure that all team pages are up to date and include links to reports and presentations.

Investments team ↥ CEE 2550 only (or through Cornell Business)

Skills: Writing, networking, business plans, financing

Introduction

AguaClara is working with communities that have the economic potential to pay for their water infrastructure if there is a suitable loan mechanism. Given a loan with a reasonable interest rate, the communities would be able to pay the loan back using the monthly water tariff. If this mechanism for financing water treatment infrastructure can be developed it has the potential to greatly expand the number of communities that can acquire safe water on tap.

Big questions to answer

- Who are the potential investors?

- What is required to pilot this new financial mechanism?

Tasks and goals

- Coordinate with Skyler Erickson, Agua Para el Pueblo, AguaClara Reach, banks in Honduras
- Craft a financing system that treats communities with respect and provides mechanisms for reducing risks and for enabling communities to acquire safe water on tap.

Apps and Algorithms Teams

AguaClara Infrastructure Design Engine ↥

Skills:Python, Fusion 360, AguaClara Design

Goal is to recruit a team of about 8 students that includes coding, CADing, and design experts.

Introduction

Cornell's AguaClara program is assembling a team to develop the first ever Fusion 360 open-source infrastructure design engine. This technology will allow engineers around the world to design complex infrastructure using simple parameters with the click of a mouse. The team will architect, develop and test the engine, using the latest design technologies available. AguaClara Engineers will then use the design engine to build water treatment plants throughout the world. The engine will take in parameters (for example, flow rate and wall thickness) and ultimately create a Fusion 360 drawing and a report that documents the design.

In this project, you'll have the opportunity to engage throughout a large program's full development life cycle. You'll work with an agile team and learn how to effectively break down a complex project into small, manageable components. You'll be exposed to difficult engineering concepts, and learn to navigate high level parametric abstractions. You'll even see plants that you developed the code for get built and provide clean water to thousands.

This is multiple major coding projects. The design engine will be built for ongoing evolution in AguaClara technologies. The coding will need the combined expertise of Python, Fusion 360, and AguaClara technologies. The code will be built for testing and with excellent documentation so that it can be maintained.

Big questions to answer

- What are the best practices for the various types of code that are required for this parametric design engine?
- How will a web presence be created for this design engine?
- How will the design specifications documents be created?
- What interfaces will separate the different levels of abstraction?

Tasks and goals

- Write code to design each of the AguaClara unit processes (chemical dosing, entrance tank, flocculator, sedimentation tanks, filters)
- Write code to draw each of the unit processes
- Create a design engine that designs, draws and documents a unit (or sequence of units) given the required inputs that set the design.
- Implement a database that can house all parameters of the given infrastructure.

Notes

- Fusion has both "scripts" and "add-ins". I think an add-in is just multiple scripts packaged together nicely and thrown onto the AutoDesk add in online space. I believe we should be making an add-in that will have buttons to draw different unit processes.
- Developing a clear architecture with specified interfaces is critical to splitting up work effectively and constructing highly modular, maintainable code. I've posted here the beginning outlines of a suggested program architecture.

Plant Operations Smartphone Tracker (POST) ↥

Skills: Computer science, Graphical User Interface

Introduction

POST is a collection of mobile and web apps designed to collect, visualize, analyze and communicate drinking water treatment performance data. POST is the only open source municipal water treatment data collection application available and has the potential to set a new standard for water quality reporting. We currently accept over 100 datapoints daily from 10 treatment plants, and over the next years have plans to expand beyond AguaClara plants out to the world at large. Working with POST, you will be exposed to the latest webapp paradigms and mobile tools, from the JAM-stack, to Google App Engine, to a large android application. You will work in an agile environment with a multidisciplinary team to reinvent drinking water treatment reporting.

Currently, we have four active repos we maintain:

- POST Collect: Android app used to collect plant information from the operators
- POST Aggregate: Server application used to collect, store and organize sent plant data
- POST Visualize: Android application that can give operators valuable insights into the performance of their plants
- POST Website: GH-Pages hosted website used to display information to the public at large.

Tasks and goals

We use Github issues to track various issues, enhancements and epics. Please see this project for a living list of all the features we would like to tackle this semester. Below is an overview of the main tasks and goals for this semester

- POST Collect
    - Need method to search for plant of interest for viewing data
    - Develop ways to visualize filter performance
        - Head loss as a function of time
        - Backwash events
        - Outlet slotted pipe purges
    - New form versions need to download automatically
    - Make Collect simpler. Operator should be able to open Collect, input username and password, and start sending data immediately
    - Develop optical character recognition ability to take readings directly from the turbidimeter and convert it into a number.
- POST Visualize Android
    - Add inter-plant comparative evaluators
        - Display reporting rank that is determined by which plant sent the most forms within the last week
        - Display average reporting interval
    - Add a chemical dose calibration tool
    - Add filtered turbidity water to graph
- POST Website (AguaClara.github.io)
    - Make it possible to browse the data
        - Over time
        - Filter head loss and filtered water turbidity
        - Easy to select which parameters are plotted
    - Optimize for mobile browsing
- POST Aggregate
    - Security and Updating Protocol
        - Bring production and development up to the latest aggregate code and develop a protocol for keeping it up to date in the Wiki.
    - Develop new plant procedure and determine scaling bounds
        - A new plant is currently designated as a new "user" in the aggregate server. This method works and scales well, however it is not straightforward from a management perspective. We need a system for adding plants, meaning a single person responsible for adding them on the Collect AND Aggregate side and a well-written document describing the procedure.
- POST Forms
    - Handle more than one plant in a single operating group
    - Force operators to explain any data entries that are significantly different than at the previous time step.

Floc size and count app ↥

Skills: User interface, coding in LabVIEW

Tasks and goals

- Test the installer on a computer in the project lab
- Get feedback from teams for ideas to improve the app
- Create sufficient features so that project teams can begin using the app
  - Continuous histogram of particle size distribution
  - Choice of saving or discarding images
  - Clear steps for setup and calibration
    - Light settings
    - Exposure time
    - Pixel size using standard scale

Wastewater research teams ↥

Anaerobic Settled Bed Pilot (ASB or UASB) ↥

Skills: design, fluids, fabrication, Python

Big questions to answer

- Can we design a pilot 0.1 L/s treatment reactor that achieves >= 50% COD removal of wastewater (blackwater?, settled Blackwater?, settled mixed WW?, raw mixed WW?)
- What are best configurations of incorporating UASBs into a “typical” WWTP scheme?
- Can UASBs work with low temp (20C or so) WW
-

Tasks and goals

- Communicate with Erika Tenorio at Zamorano about possible pilot plant testing of ACWW design there in HOnduras that her students can get involved with
- Communicate with Ithaca wastewater treatment plants for collaboration, space limitations and what they can monitor. This may dictate the design (size) of the pilot plant.Also discuss whether we treat primary settled ww or raw ww (get info on water quality parameters e.g. COD, suspended solids).
- Design a pilot-scale UASB reactor considering AguaClara designs and the needs and recommendations of Honduran plant operators
  - Create Python, Fusion 360 documentation

    - Include sludge hopper, plate settlers/GLS separator
- Start fabricating a portable plastic pilot UASB once a design is ready
- Preliminary jar testing for coagulation, flocculation, floc blanket, and sedimentation as a UASB post-treatment option (perhaps using IAWWTF digester effluent)
    - COD, BOD, TSS, coliforms, TKN, phosphorus

Water Quality Monitoring for Diarrheal Pathogens ↥

Skills: water sampling; hydraulics; computer aided design; microbiology

Big questions to answer

- How polluted with pathogens are surface and groundwater resources in Honduras?
- In the Global South, water quality monitoring is sparse and motivation to invest in water and wastewater treatment could be improved by documentation of contamination of water supplies. We want to be able to monitor Fecal contamination (especially enteric pathogens) in order to 1) benchmark which enteric pathogens are prevalent in a water supply and 2) document AC plants' ability to remove bacterial, protozoal and viral pathogens that cause Gastrointestinal illness.
- A major challenge for fecal indicator bacteria (FIB, eg. E coli or enterococci) monitoring is finding methods that are appropriate in the global south (e.g. Compartment Bag Tests). We field tested CBT in AC plants in January, May and June 2016 to show robust removal of E coli by AC plants. Broader surveys could be done to monitor more locations or over longer time periods.
- For actual pathogen monitoring, DNA-based detection/quantification is very powerful and poses fewer risks than culture-based pathogen detection (which grows harmful pathogens on purpose in the lab). The Richardson lab has recently designed a PCR-based "array" (on the OpenArray platform) to monitor 12 diarrheal pathogens, 2 FIB, and 3 source specific marker genes (human poop, cow poop, bird poop) and we would like to use this to detect/quantify actual pathogens in Honduran drinking water raw supplies and AC produced water.However, large volumes of water must be processes compared to tests for just FIB. Practical, simply workflows are needed (with inexpensive supplies) to process ~10 L samples into concentrated biomass with <5 mL water volumes and/or membrane-caught microbes.

Tasks and goals

- Read up on EPA certified methods and other published protocols
- Brainstorm ideas for how to capture/collect viruses, bacteria and protozoa from a large sample to a ~5 mL residual liquid volume (or less) plus membranes up to 47 mm in diameter. Ideas include use of dialysis membrane units (Rexeed 25S) for concentration;
- Test for clogging of biomass collection procedures at different turbidity levels (e.g. by taking Cascadilla creek water as start and adding kaolin clay to different NTU levels).

- Test different ways of forcing water thru (gravity; pushing; pulling; hand pumps vs electrical pumps)
- Read up on the OpenArray technology and pathogen DNA levels
- In January 2018 collect and process water samples in Honduras and ship back to the US for DNA extraction and OpenArray analysis at the Veterinary College Diagnostic Lab.

Resources for new team:

- our recent WERF preproposal
- papers on concentration of large water samples' biomass to get DNA/RNA from the biomass for further testing
- papers on the OpenArray technology/PCR in general.
- our paper on CBT levels
- Hudson river Walkill river preliminary data.

Particle Removal Research Teams ↥

Our goals are to reduce the capital cost, reduce the operating cost, and improve the particle removal efficiency so that the AguaClara technologies are the best. We want to...

- Assess the utility of a contact chamber after rapid mix to allow diffusion to transport nanoclusters to coat the particle surfaces
- Test higher rate sedimentation tanks
- Design and test tapered flocculation to increase the floc volume fraction that is actively growing from collisions
- Learn what controls performance of sand filters
- Improve the performance of the StaRS filters especially in regard to clogging of the slotted pipes

Contact Chamber ↥

Skills: Fabrication, fluids, Python, ProCoDA

Big questions to answer

- What is the physics that determines the rate of coagulant nanoparticle transport to clay particles? We expect diffusion to control transport. We'd like to develop equations to predict the time required for a target fraction of the coagulant nanoparticles to attach to the clay particles.
- What are the equations that describe the process? (molecular diffusion, shear)
- What is an optimal/reasonable design for a contact chamber?

Tasks and goals

- Design a contact chamber that minimizes contact of incoming fluid with the chamber walls. This can be accomplished by using a pipe as the contact chamber and having the inlet be in the center of one of the ends. Set the length of the contact chamber to be approximately 10D.
- Vary the residence time in the contact chamber by varying D while keeping L/D constant.

Reactor design guidelines for Contact Chamber, High G Flocculator, High Rate Sedimentation, and all of the Dissolved Species Removal teams

parameter	value	comments
Flow rate		Set to give upflow velocity of 3 mm/s in sedimentation tank
Sed tank diameter	1”	Use the same diameter as the Fluoride team
Coagulant dose		Estimate a dose (using floc_model.py) that will give a settled water turbidity of 2 NTU. Goal is to have settled water turbidity of approximately 1 (0.3 to 3) NTU so that changes in performance are easily measured by the turbidity meters.
Coagulant feed		Evaluate the possibility of using smaller diameter coagulant pump tubing so you can use higher concentration stock. Goal is to minimize the dilution of the PACl stock and to eliminate the need to place the stock on a stir plate. Instead the stock should be placed on an electronic balance so that the feed rate of coagulant can be confirmed
Raw water turbidity	10 NTU	Use a low turbidity so that loss of coagulant to the flocculator walls is very high (Estimate this loss using floc_model.py)
Contact chamber residence time		Series of different pipe diameters and lengths with a range of 10 to 300 seconds
Flocculator design	Gt, d, L	Use flocculator design (modified for the increased flow rate given the increase in sed tank diameter) from the summer 2017 High Rate Sed team
Floc blanket depth	0.25 m	This is a guess and the 3 teams can decide the baseline sed tank design. The sed tank presumably has a vertical section that is 25 cm, a 60 degree angle from the horizontal with a capture velocity of 1 mm/s, a floc hopper right above the sloped section, a second sloped section with a capture velocity of 0.36 mm/s when operated at 3 mm/s upflow velocity
Time lapse recording		Use a Time Lapse Video Camera to track floc blanket position over time (one team member can design this system including camera, lighting, and a camera mount)
		Use Reverse Osmosis water to prepare stock solutions of PACl

High G Flocculator ↥

Skills: Fabrication, fluids, Python, ProCoDA

Big questions to answer

- What is the physics that determines the optimal G value for flocculators? One hypothesis is that the goal is to have high shear so that max floc size is tiny so that clay particles have better chance of a successful collision with the flocs. Excessive shear may produce flocs that are so small that they don't settle at 0.12 mm/s and thus are carried through the tube settler.
- What are the equations that describe the process?
- What is the optimal G value for flocculators?

Tasks and Goals

- Use the same base design for the experimental apparatus as the Contact Chamber team.
- Vary G and theta while holding Gtheta almost constant. This can be accomplished by varying the flow rate through the flocculator and then using a peristaltic pump to SUBTRACT excess flow so that a constant flow rate corresponding to an upflow velocity of 3 mm/s enters the sedimentation tank. Vary G from 100 to 500 Hz (100, 200, 300, 400, 500 Hz). It may be necessary to using a larger diameter flocculator then was used in the summer of 2017 by High Rate Sed to achieve the low G value.
- Vary the coagulant dose to see if the optimal flocculator G is a function of the coagulant dose.

High Rate Sedimentation ↥

Skills: fabrication, ProCoDA, experimental design

Big questions to answer

- How does floc blanket performance vary as a function of upflow velocity in the floc blanket?
- What geometry is necessary to form a stable floc blanket under conditions of high upflow velocity?
- Where should the floc hopper weir system be installed?
- Does the floc blanket improve performance? (We don't yet have a model for floc blanket performance.) Resuspension of flocs will still be useful to maintain a zero sludge sed tank even if the floc blanket does not significantly improve performance. It is also possible that in full scale sedimentation tanks that the floc blanket plays a critical role in generating uniform upflow velocity through the plate settlers.

Tasks and goals

- Use the same base design for the experimental apparatus as the Contact Chamber team.
- The big goal is to determine the maximum upflow velocity and to develop an improved (or even THE OPTIMAL) design for sedimentation tanks. This problem is complex because it is influenced by flocculator and by the plate settlers.
- Vary geometry including floc blanket depth, method of controlling floc blanket height, sloped section to increase floc blanket concentration. Goal is to identify mechanisms, best geometry, and minimum size.
- Vary coagulant dose and clay concentration to test performance of selected geometry to make sure that it is robust over a wide range of operating conditions.

Filter Constrictions ↥

Skills: lab experience, fluids, ProCoDA, Python

We have strong evidence from both the milli-sed team and the StaRS Filter team that particles are captured preferentially at flow restrictions in sand filters. The constriction filtration hypothesis is as follows. The flow restrictions cause the streamlines to contract and thus particles that are near the sand (the edge of a pore) move closer to the edge at the contraction. This results in preferential deposition of particles at contractions. Particle collisions continue to be more and more frequent at the contraction as the contraction becomes smaller. Eventually the velocity through the constrictions increases to the point where the drag on particles that collide with the constriction is sufficient to rotate the particle through the constriction so that attachment does not occur.

Big questions to answer

- Can we create a video showing gradual accumulation until shear is too high?
- Do flocs accumulate in a 2-D pore in the same way that they do in axisymmetric pore? It is possible that a growing line of flocs is unstable and rotates off of the wire.
- Can you obtain a clearer video by using both front and back lighting or by changing the angle of the camera?
- Can you measure the probability of attachment of different sizes of particles?

Tasks and goals

- Add a flow accumulator and a head loss element after the tap water pump and before the clay and coagulant to eliminate flow pulsation
- Determine why the streamlines appear to be curved in the sample cell
- Consider increasing the raw water turbidity to speed up the process of particle deposition
- Take a video that shows flocs/particles depositing on the flow restriction and building up so that flocs are attaching to flocs.

StaRS Filtration theory ↑

Skills: lab experience, fluids, ProCoDA, Python

Big questions to answer

- Are the flow restriction/particle impingement/maximum drag hypotheses correct?
- Do filters remove primary particles or only flocs?
- Why do some particles make it through filters?
- Is particle removal efficiency independent of filter bed depth?
- Consider varying sand grain size to measure this effect
- Are there predictions from the model that could be tested?
- Can the model be extended to predict head loss as a function of coagulant dose (based on strength of bonds as a function of coagulant dose)?

Tasks and goals

- Finalize and submit the paper on the flow restriction model
- Develop an experimental plan based on the hypotheses that you would like to test or based on the additional capabilities you would like to add to the model
- It is possible that rigid particles can not be easily removed by flow restrictions because at least half of the particle will be overhanging the restriction into the flow and the shear will tend to rotate the particle off of the restriction and only a small number of coagulant nanoclusters will be engaged at a time. Thus rigid particles will tend to rotate off of the restriction and continue through the filter. Deformable flocs will be able to make many points of contact with the restriction as they deform and drape over the edge of the restriction. Test this hypothesis by using the floc app to measure removal efficiency as a function of particle size.

StaRS Outlet Slotted Pipe Upgrade

Skills: Fabrication, fluids, Python, ProCoDA

Introduction

StaRS Filters were invented by AguaClara in 2010 and since then they have evolved rapidly. Maintenance requirements for StaRS filters have been higher than anticipated because the injection and extraction systems clogged over time. Initially slotted pipes with 0.2 mm slot width were used for both injection and extraction. The injection system has been improved by replacing the slotted pipes with orifices that are protected from sand intrusion using wings that lower the sand water interface during backwash. The last slotted injection pipes at an AguaClara plant in Honduras were recently upgraded.

The slotted extraction system does not clog as quickly as the slotted injection system, but now that the injection system has been upgraded it is apparent that head loss does slowly build in the slotted extraction pipes. It is very likely that clay particles that are coated with coagulant nanoparticles are depositing either at the entrance to the slots are within the slots and that build up is slowly increasing the head loss through the filters.

In the spring of 2015 the [Stacked Rapid Sand Filter Theory Team investigated slot clogging](). Their results suggest that clay and coagulant flocs are depositing in the slots. They cleaned the slots with acetic acid.

Big questions to answer

- How can maintenance of StaRS filters be reduced?
- Would a completely different geometry of injection and extraction be possible that would eliminate this problem (for example, vertical sand layers rather than horizontal sand layers so that pipes would be spaced close together vertically and far apart horizontally to facilitate backwash).
- Would rounded entrances into the slots decrease the number of particles that impinge on the edge of the slot?
- Could we increase the slot area either by increasing the slot width (Bigfoot sells 0.008", 0.010" 0.012", 0.015", and 0.018" slots) or by increasing the number of slots?
- PVC VEE-WIRE ® SCREENS to increase open area

Tasks and goals

- Review previous research on slot clogging
- Explore all possible methods to either replace slots, change the slots so they don't clog as quickly, or invent a new method of cleaning the slots.
- Explore using larger slots (see Big Foot Manufacturing Company). Obtain samples of larger slots and test using sand. It may be best to obtain a sample of sand from the same company that supplies sand for the AguaClara plants in Central America.
- Explore cleaning with dilute acid and assess if this could be used at full scale.

1 L/s plant testing ↥

Skills: Fabrication, fluids, Python, ProCoDA

Big questions to answer

- How can the pilot plant be operated for sufficient periods of time to collect meaningful performance data? (Yes because we can now operate at 1 L/s without recycle)
- Do all of the plant controls work well?
- Can the filter controls be improved?
- How large must the floc hopper be to handle high turbidity events?
- Is tapered flocculation better than constant energy dissipation rate flocculation?
- Is rapid mix needed when all of the flow goes to a single flocculator?

Tasks and goals

- Design a PACl feed system that can provide PACl dosages from 0.2 to 2 mg/L of Al. Use the maximum concentration of stock possible. If needed you can switch the chemical dosing tubest to be smaller in diameter. It is likely that 1/16" tubing will be a better design than the ⅛" tubes
- Use continuous make up water with recycle to maintain pH above 6.5. Coagulant addition lowers pH and this will be a problem with recycle if insufficient make up water is provided
- Design a method to maintain the a constant volume of water in the apparatus.
- Draw an elevation view of the system showing how water levels with vary and be controlled during idle, filtration, and backwash.
- Verify that the system doesn't overflow at any point in its operation.
- test effectiveness of tapered flocculation at reducing filtered water turbidity
    - Design a 3 stage tapered flocculator where first stage has a G of approximately 350 Hz, 2nd stage has a G of approximately 35 Hz, and the 3rd stage is the floc blanket with a G of approximately 3.5 Hz. Set the Gθ to be a total of 20,000 in the first two stages. Perhaps Gθ for the first stage could be 15,000 and Gθ for the 2nd stage would be 5,000.
    - Design a 2 stage flocculator to have the same head loss and residence time. Compare the 3 stage and 2 stage flocculator performance using the 1 L/s plant operating with a floc blanket
- Remove the rapid mix from the uniform energy dissipation rate flocculator and see if there is a detectable difference.
- Test effectiveness of the contact chamber at a low raw water turbidity (perhaps 5 NTU).

Dissolved Species Removal Research Teams ↥

The removal of dissolved species using floc/sed/filter systems opens opportunities to bring low cost safe drinking water to communities that are using groundwater contaminated with arsenic or fluoride. Our goal is to develop a good reactor geometry at bench scale using 2.5 cm diameter columns and then build a 0.1 L/s pilot plant for demonstration in India. The 0.1 L/s plant will ideally be built during the spring of 2017 and taken to India in the summer of 2017. The following year we will scale to a 1 L/s plant that could provide safe water for a village of several hundred people.

Fluoride floc blanket removal ↥ (EPA P3 Phase II grant)

Skills: fabrication, ProCoDA, experimental design

Big questions to answer

- Can higher upflow velocities in the sed tank maintain a fluidized bed of flocs even without ANY clay addition? Elimination of clay is a high priority goal for the first part of the semester
- How low of a PACl dose can be used and still achieve the target effluent Fluoride concentration?
- After achieving the previous two goals, then check, does adding a countercurrent floc blanket improve fluoride removal efficiency?

Tasks and goals

- Create a floc blanket resuspension geometry that doesn't compress flocs as they approach the resuspension jet with the goal of creating a stable high concentration floc blanket
- Measure red dye #40 removal efficiency and stability of reactor performance for a single reactor with a range of upflow velocities to obtain an optimal velocity for further testing.
- Measure red dye #40 removal efficiency and stability of reactor performance for a countercurrent floc blanket reactor
- Determine if countercurrent reactors should be used for pilot scale field testing
- Begin designing a 0.1 L/s (approximately) scale reactor. Note that if countercurrent floc blanket reactors are effective then this technology might have widespread application including for surface water treatment plants especially for improved removal of dissolved organics.

Humic acid, kaolin, floc/sed model ↥

Skills: fabrication, ProCoDA, experimental design

Introduction

The AguaClara flocculation model is able to describe flocculator performance based on the simple idea that coagulant nanoparticles are sticky and that clay particles and humic acid macromolecules aren't sticky. The probability that any collision is successful can be estimated based on the probability that coagulant is present at the collision site. There is some evidence that coagulant-coagulant bonds are weaker than coagulant-clay bonds. Water treatment plants that are treating waters with high concentrations of natural organic matter (NOM) and low turbidity can easily approach a situation where the NOM coats so many coagulant nanoparticles that there isn't enough space on the clay for all of those nanoparticles to attach in a single layer.

Big questions to answer

- Under what conditions is the floc model able to reasonably predict performance of Humic Acid (HA) and turbidity?
- Does the switch to higher G in the flocculator (compared with Yingda Du's research) result in significantly better performance for the removal of HA

- How will we measure humic acid removal efficiency? One possibility is the HF Scientific LED Online UV Analyzer.

Tasks and goals

- Use the same base design for the experimental apparatus as the Contact Chamber team.
- Hold the HA concentration constant at 15 mg/L
- Vary coagulant dose (0.5 to 3 mg/L as Al) and raw water turbidity (0 to 500 NTU) to see how well the flocculation model describes performance. Use coagulant dosages that are high enough to cause poor performance.
- We need to determine whether it is best to include the floc blanket in this research or if we should exclude the floc blanket to more closely replicate Yingda Du's research.
- Test the ability to remove humic acid for water that contains no clay particles using a single injection of coagulant. Use Yingda Du's thesis and the flocculation model (floc_model.py) to estimate the ratio of coagulant to HA that achieves complete coverage of the coagulant nanoparticles by the HA (it should be approximately 1 mg/L Al per 15 mg/L HA). Use coagulant dosages starting at this value and increasing by 0.25 mg/L as Al. Use 15 mg/L HA.
- Sketch clay, coagulant nanoparticles, and humic acid (HA) macromolecules for the case where there are so many HA macromolecules that HA coated coagulant nanoparticles can't all attach to clay particles. Explore the possibility that an initial dose of coagulant provides just enough surface area so that all HA attaches to and completely covers the coagulant nanoparticles. Then in a second step add more coagulant nanoparticles that can attach to multiple HA coated coagulant nanoparticles. Develop a model for how much additional coagulant would have to be added to create flocs of HA coated coagulant nanoparticles.
- Observe performance of sedimentation tank and floc blanket under the extreme condition of no clay.

Two Stage Coagulant Addition ↑

Skills: fabrication, ProCoDA, experimental design

Introduction

Water treatment plants that are treating waters with high concentrations of natural organic matter (NOM) and low turbidity can easily approach a situation where the NOM coats so many coagulant nanoparticles that there isn't enough space on the clay for all of those nanoparticles to attach in a single layer.

Big questions to answer

- Does 2 stage addition of PACl aid in the efficient removal of Humic Acid (HA)? If two stage coagulant addition is helpful this would be a relatively easy design change for water treatment plants. Our geometric flocculation model can help provide insight into why this might be helpful and how to optimize the two dosages.

Tasks and goals

- Use the same base design for the experimental apparatus as the Contact Chamber team.
- Test the idea of adding a second dose of coagulant after the first contact chamber and before a 2nd contact chamber. Assess which method is better, single stage or double stage coagulant addition.

Fabrication and Physics teams

Ram Pump ↥

Skills: Fabrication, fluids, physics

Introduction

The ram pump has already proven to be a very useful addition to AguaClara plants because it can pump treated water to the top of the plant for use in mixing chemical stocks as well as for use in the bathrooms. The ram pump design is far from optimal and it seems likely that the spring design that we have been using is not appropriate.

Big questions to answer

- How can we modify the ram pump design so that the main valve remains closed until water stops flowing into the high pressure line?
- How can we create a design that allows the main valve to open far to reduce head loss across the main valve?
- How do you methodically tune the new inline ram pump?

Tasks and goals

- Sketch the forces acting on the valve at moment after it closes, right before it opens, right after it opens, and right before it closes. Develop an understanding of what is required for the valve to cycle automatically.
- Develop a method to take high speed video of the valve cycle with sufficient resolution to measure the time that the valve is closed.
- Estimate the time that the ram pump waste valve should remain closed per pump cycle assuming that the valve closes when the flow is equal to 75% of the maximum flow rate.
- Estimate the static force of the water column acting on the waste valve at the end of the pump cycle and hence the force that the spring must provide to open the valve.

- Design a spring system that would provide the force to open the valve and provide a very small amount of force to keep the valve opened approximately 1 cm (if this is possible).
- Develop a methodical approach to tune the ram pump and see if you can get it working with 1 m of head.
- Document this tuning method and send it to Honduras for their use
- Take the necessary components of this new design to Honduras for demonstration in January.
- Assess whether it would be worth creating a design that only requires one large check valve. If so, develop an alternate method to stabilize the valve shaft.
- Create a detailed 3-D AutoCAD drawing
- Write a research paper detailing the design, tuning, and performance of the new ram pump

Sensor Development ↥

Skills: electronics, fluids, fabrication, ProCoDA, electrical engineering, computer science

Big questions to answer

- Can we create additional sensors that will help us learn more about water and wastewater treatment?
- Can an Android phone provide power for a USB sensor (for the LED) and either measure the returned voltage OR power an external Analog to Digital Converter and then communicate with the sensor over the USB cable?

Tasks and goals

- Fluidized bed solids detector (for 1” PVC reactors)
    - Test photosensor with any of the floc blanket reactors
    - Exploring the possibility of using 3-D printing to build the sensor system that wraps around 1” PVC pipe
    - Manufacturer several of the sensors to be installed on laboratory floc blanket reactors
- Submersible solids detector for floc blankets (for AguaClara plants)
    - Develop a probe that can measure floc blanket concentration by being submerged in the floc blanket.
    - Design a microprocessor based system or an Android phone to display the resulting solids concentration
    - Test the ability of this probe to both measure floc blanket concentration and to detect the location of the sludge water interface in the floc hopper. Use the 1 L/s plant to test the probe.
    - Take a working prototype to Honduras in January

Flow control for modular EStaRS ↥

Skills: fluids, fabrication

Big questions to answer

- Can a simple, modular flow control system be added to the EStaRS entrance tank to enable equal division of the the flow during filtration and to allow the filter that is being backwashed to receive the design flow rate?

Tasks and goals

- Design a weir system that can be incorporated into an EStaRS entrance tank. Use the weir system that is used for the OStaRS filter as a conceptual guide.
- Develop a fabrication method for the weir system that makes it easy for the operator to switch to backwash mode.
- Coordinate with the APP workshop to make sure you are using any best practices that they have developed
- Share the resulting design with the APP workshop and document the design
- A 2nd related task would be to develop a method to divide the flow between 1 L/s plants with the flow being split after the contact chamber.

Tasks for Honduras trip 2018

- Measure batch flux curve for floc blanket solids (This was attempted done on 2017 Honduras trip). Use this to design the floc hopper
    - (ceeserver.cee.cornell.edu/jjb2/cee6560/3-Sedimentation.ppt)
    - http://www.joelbchristian.com/thickener/thickener.html
- Do plant operators observe floc failure at high coagulant dosages? Ask this at all plants (failed to do this on 2017 trip).
    - Purchase pH probe to take along on trip to measure pH
    - Consider doing a titration with the PACl to get coagulant dose at pH 6.5 (pH at which flocculation begins to fail) (done on 2017 trip)
- Prepare for measuring water quality in the field

Tasks without a home yet

- Develop design constraints for floc hoppers
    - (ceeserver.cee.cornell.edu/jjb2/cee6560/3-Sedimentation.ppt)
    - http://www.joelbchristian.com/thickener/thickener.html
    - Determine what data must be collected in January 2018

- Measure adsorption isotherms for fluoride

Prove that floc blanket in the plate settlers causes a decrease in performance. Determine if it is due to high velocity water (a jet) that causes turbulence and hence vertical mixing.

We need a method to predict the required coagulant dose. Presumably we need a measure of DOM and turbidity. The challenge is how to measure DOM in the raw water. Might there be a creative solution? Or is the best option to use the floc size app after flocculation?

Aeration ↥ (pending project)

Skills: fabrication, ProCoDA, experimental design

Source water often comes supersaturated with dissolved gasses. This supersaturation can be caused by high pressure transmission lines that carry a mix of air and water as they cross valleys on their way to the plant.
Aeration is an inefficient process in part because air and water have such different densities and thus it is difficult to keep them in contact with each other for very long.

Big questions to answer

- Could we add an aeration step to reduce dissolved gas supersaturation? This would decrease the rising floc problem that causes poor performance in the sedimentation tanks. It could also be used to strip methane for anaerobic digester effluent. It would also be beneficial for removal of arsenic and iron in groundwater treatment systems

Tasks and goals

- Contact chamber modeled after a floc blanket
  - Invent a downflow fluidized air bubble reactor system. (calculate rise velocities of bubbles and set downflow velocity to prevent bubbles from rising. Use venturi at inlet of reactor to pull air into the stream of water.
  - The downflow system will need a method to inject a small amount of air (likely a venturi) with the incoming water. The injection of air bubbles with LFOM's at AguaClara water treatment plants provides an additional proof of concept that air bubbles can be entrained and carried downward.
  - The downflow velocity should be high enough to prevent bubbles from escaping upward to create a fluidized bed of bubbles
  - Big question is whether the fluidized bed of flocs will be stable given that bubbles can collide and combine