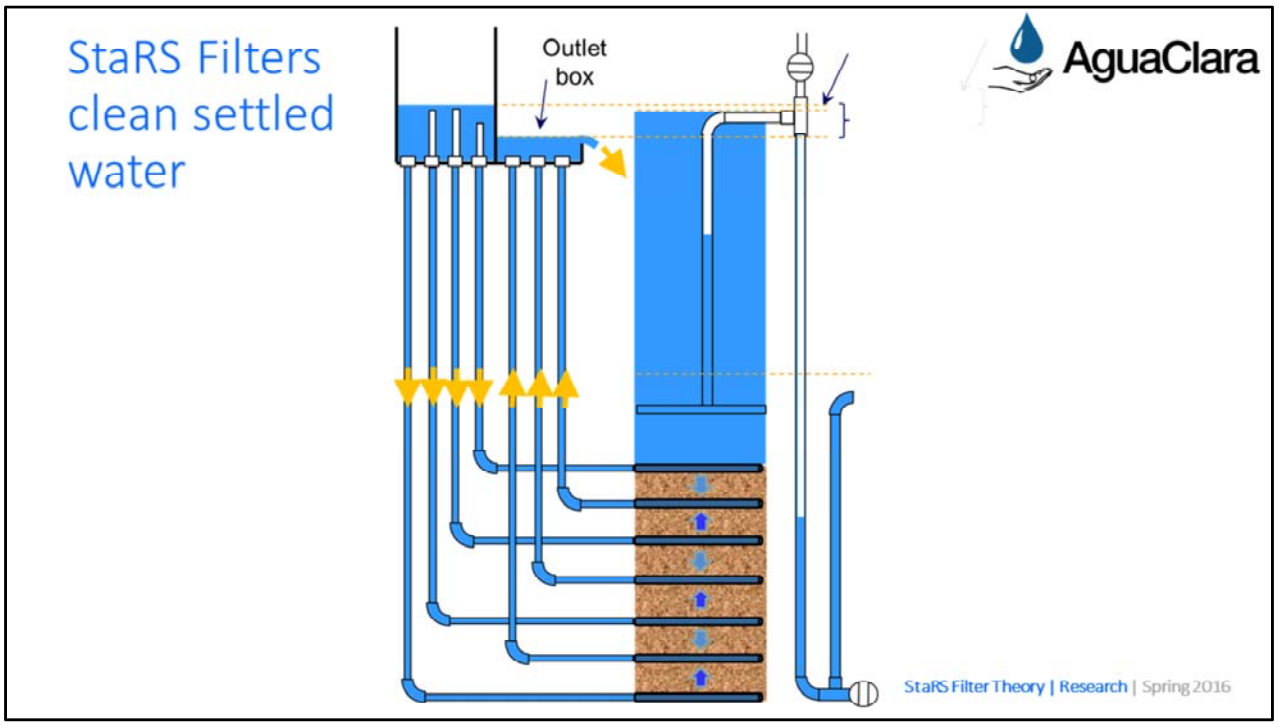
AguaClara

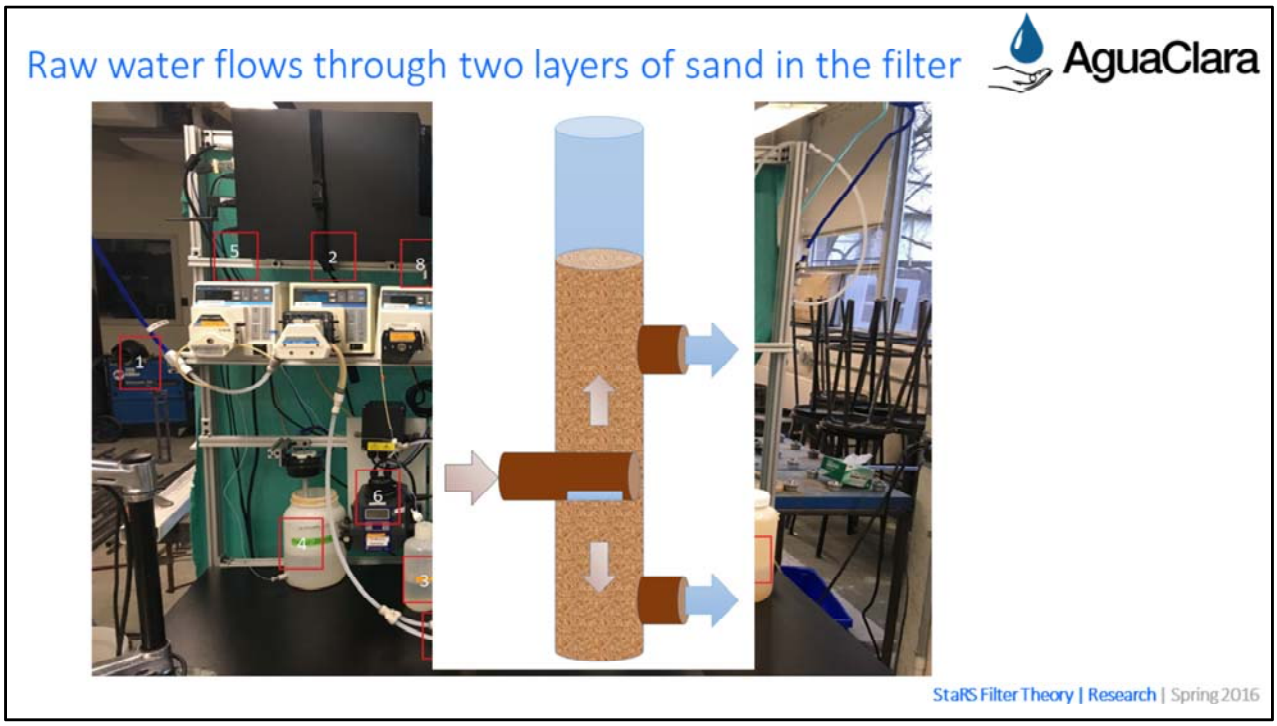
Stacked Rapid Sand (StaRS) Filter Theory

Experiments testing the effects of varying coagulant dosages on filter performance showed the impact of coagulant on head loss and effluent turbidity. Find more information at StaRS Filter Theory's wiki.

StaRS Filter Theory | Research | Spring 2016

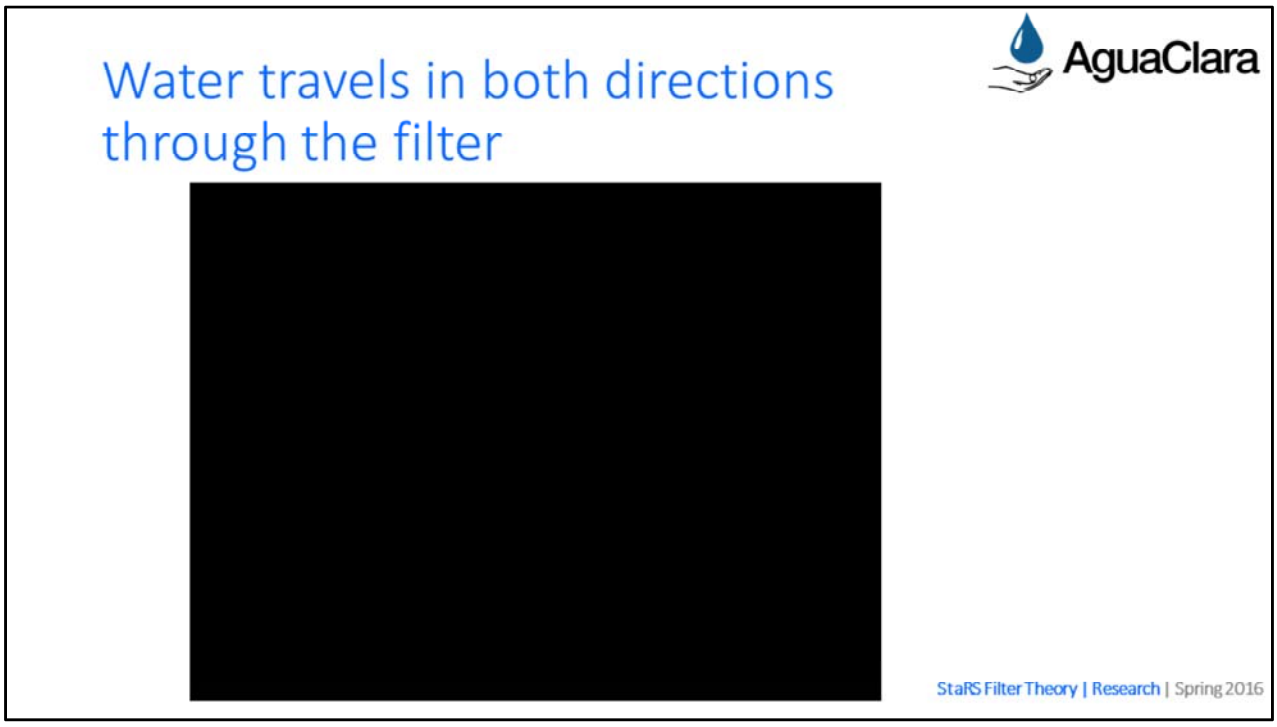


Stacked rapid sand filters clean settled water after sedimentation and removes fine particles that were not removed in previous processes. Settled water enters through four inlet pipes and clean water exists through three outlet pipes.



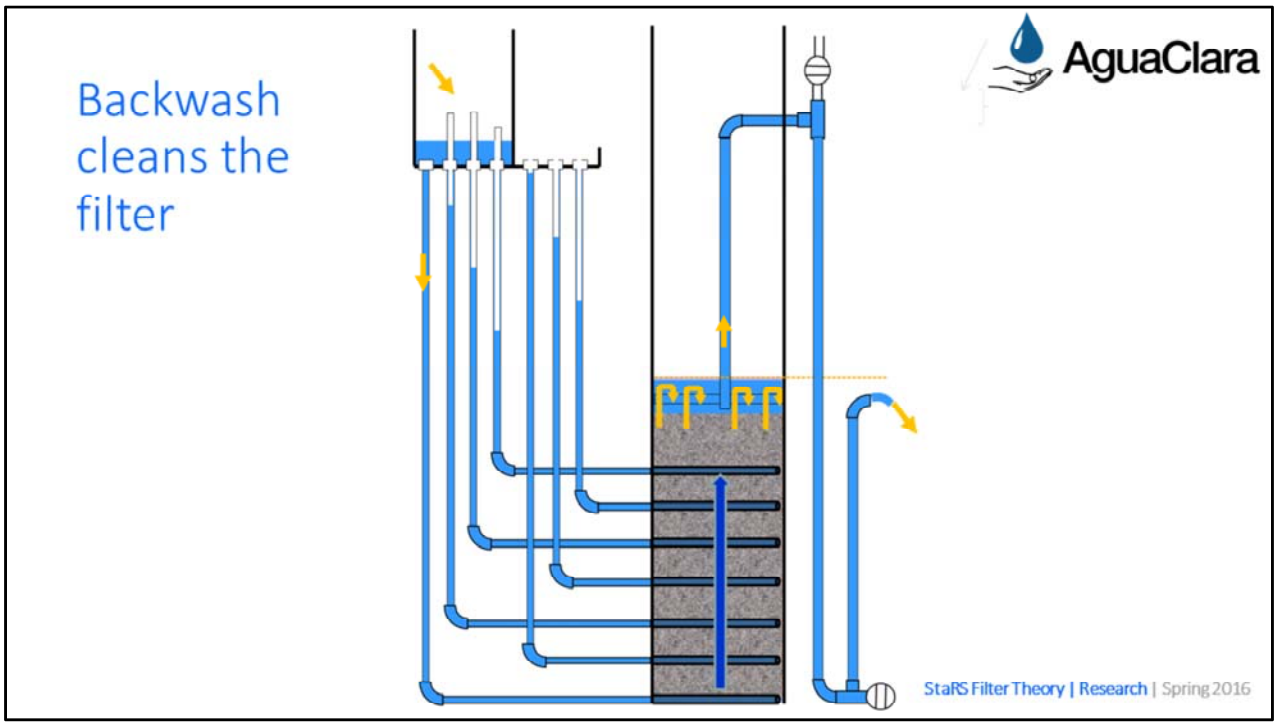
The goal of the subteam is to create a mathematical model that demonstrates a relationship between PACl dosage and headloss. In the lab, the apparatus was built to model a sand column with two layers. This allows us to model the behavior in full-size stacked rapid sand filters. The water enters the filter and flows up and down at an equal flow rate for a more evenly distributed filter, maximizing the sand area used. When pore space is filled up with particles, head loss increases until filter failure. For our purposes, we define failure to be the moment when rate of change of effluent turbidity is greater than 0. A more detailed representation of our experimental schematic can be found in appendix slide Filter Schematic.

- Goal
- Apparatus
- Up and down-distributed filter
- Pore space clog-> head loss
- Define failure
- Appendix



Jonathan

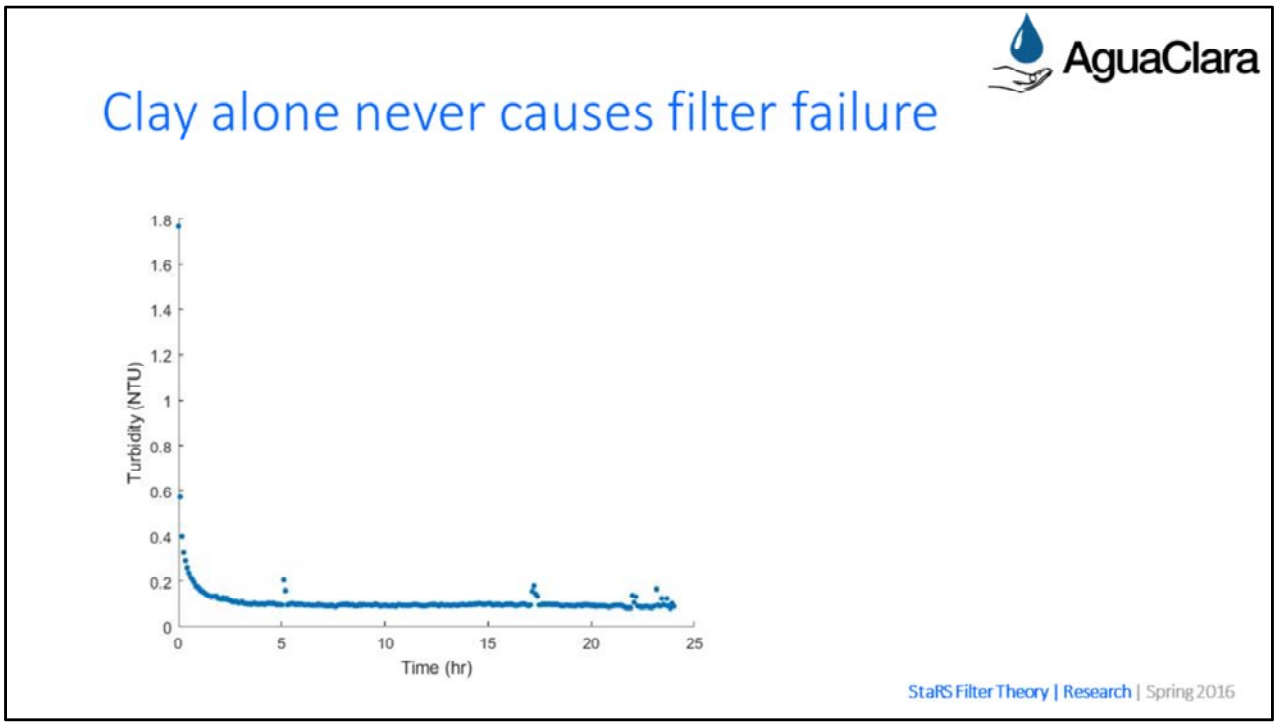
Link to filter video: https://youtu.be/DzYxWDEED8M



Jonathan (keep in final)
a process called backwash cleans the filter, relies on the difference in altitude to increase velocity for backwash

Backwash cleans the filter

Jonathan
Link to backwash video: https://youtu.be/bWEkB_z0ZjY

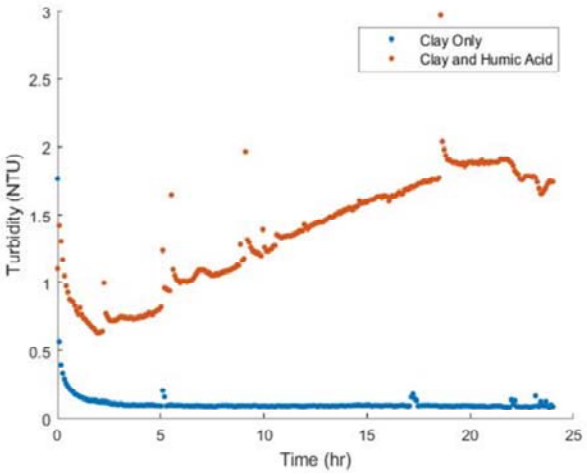


Theresa

- First control experiment: only clay, 0 PACl
- Filter never fails
- Hypothesize that the filter will fail at a low enough PACl dosage, our goal was to find the threshold dosage
- These Results show that clay only experimental condition can not help us, altered raw water mixture

AguaClara

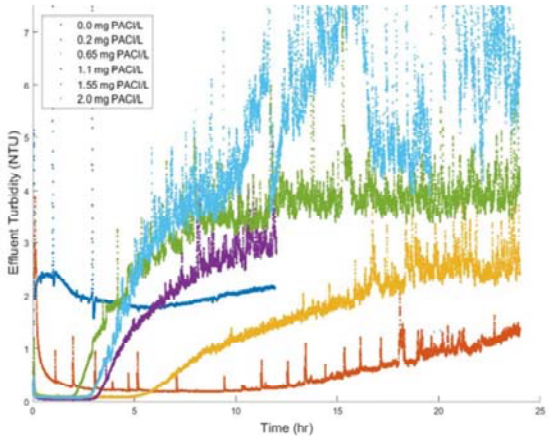
Humic acid and clay causes filter failure

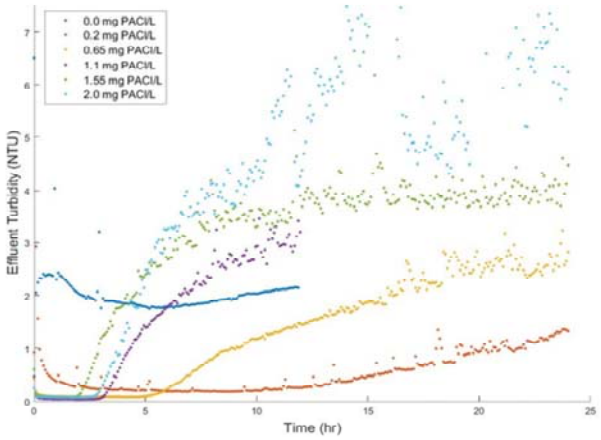


StaRS Filter Theory | Research | Spring 2016

Theresa
Experimental conditions
24 hours, 0 to 2 mg/L PACl
Clay and humic acid fails on no coagulant, which is what we want, so that we can test the effect of coagulant
Appendix slide – conditions used to test the filter

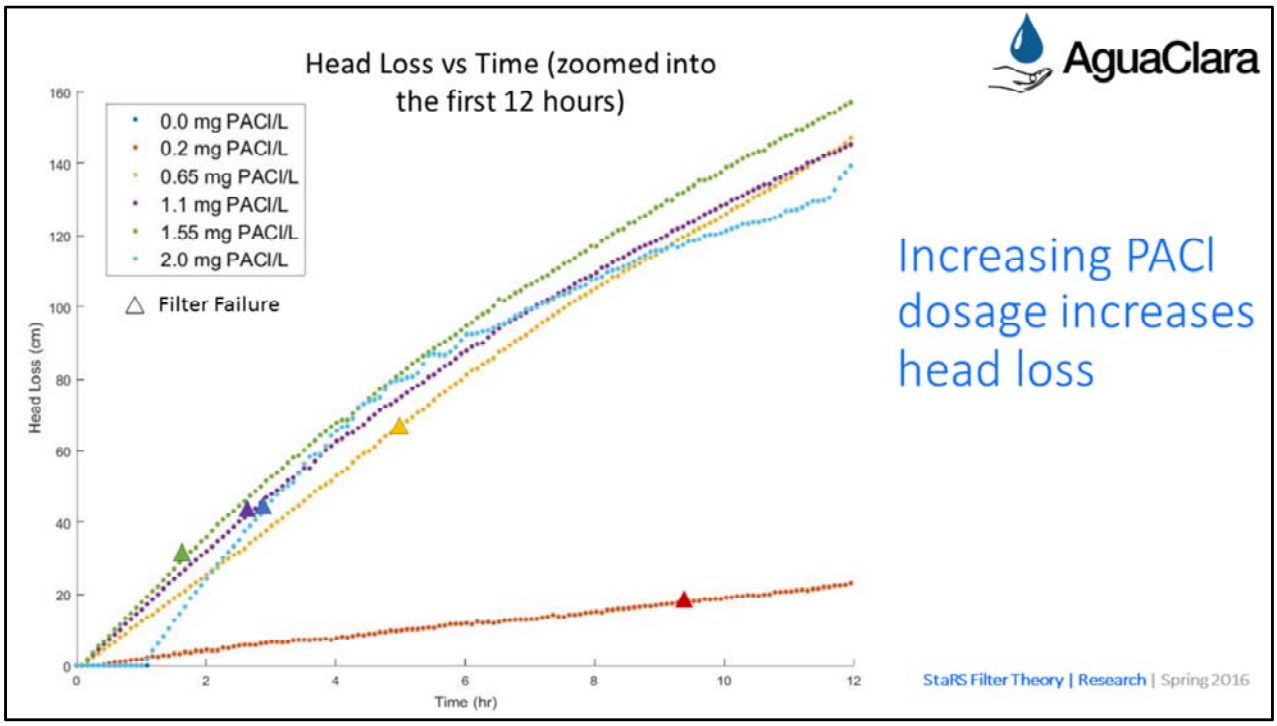
Smoothing data shows trends clearly



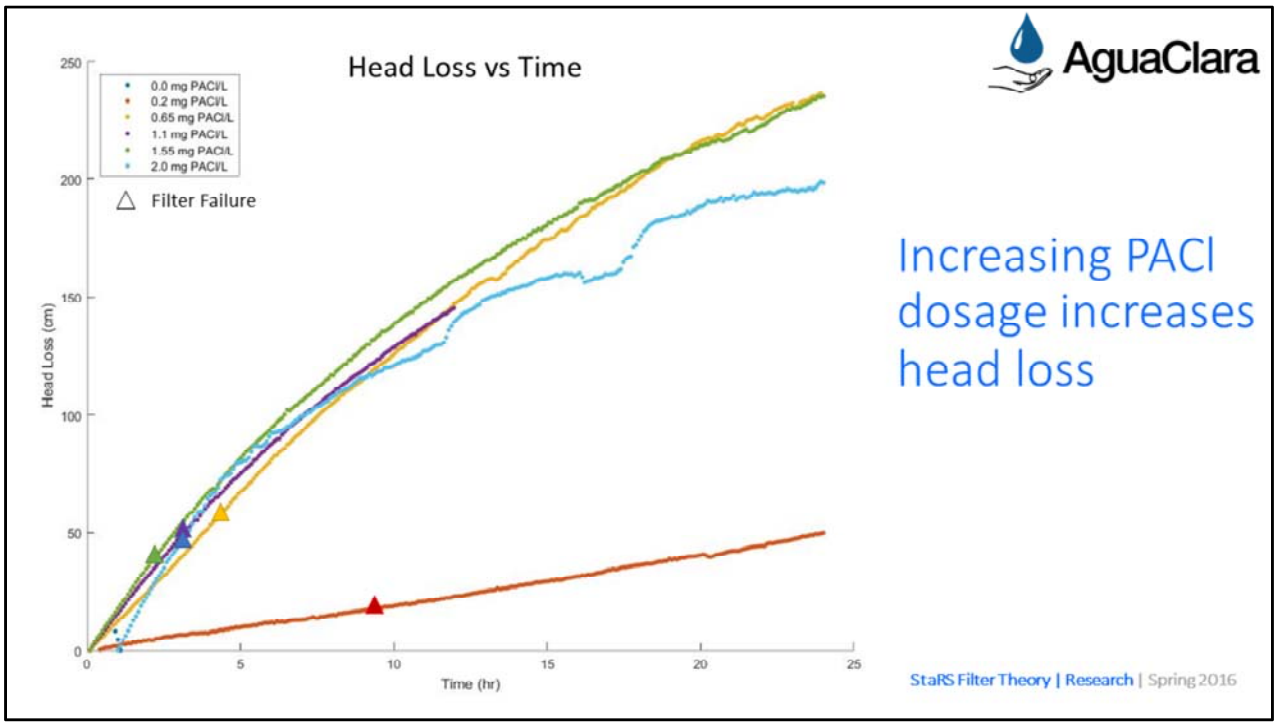


StaRS Filter Theory | Research | Spring 2016

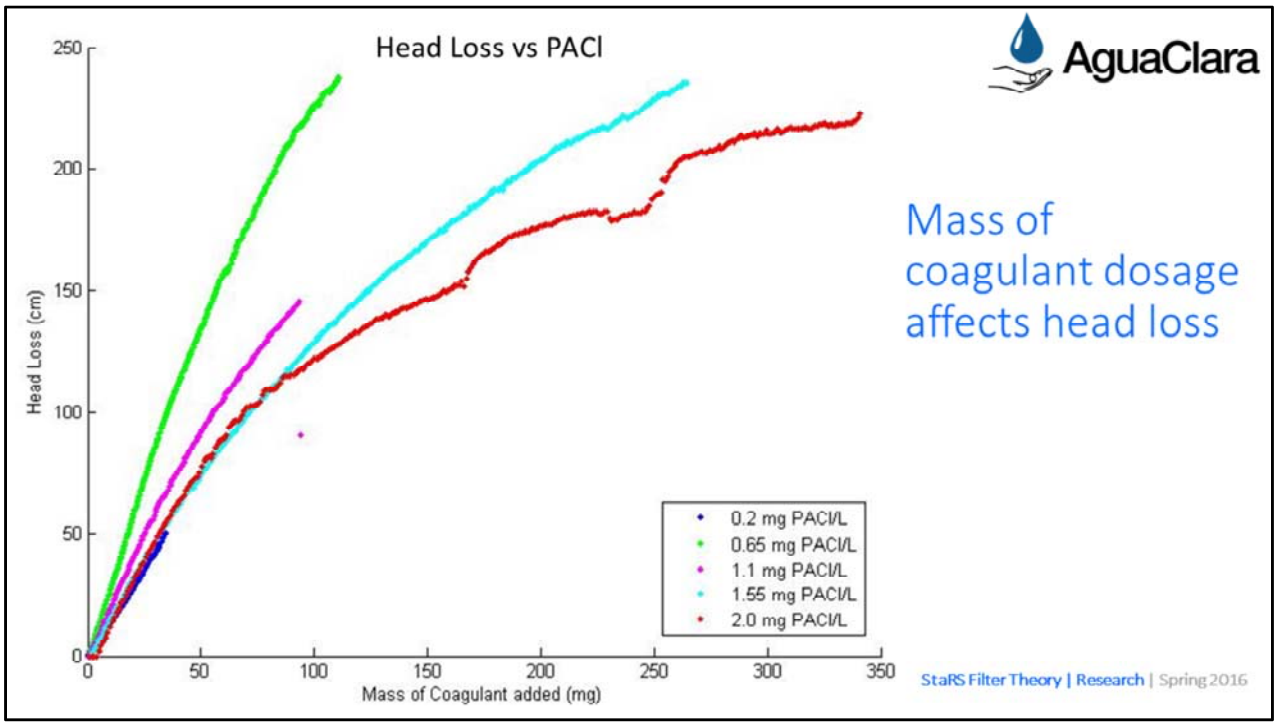
Theresa
MATLAB code was written to smooth the data in blocks, remove large jumps in head loss



Analyzing the data for experiments conducted at PACl dosages 0 to 2.0, we conclude that increasing PACl dosage increases head loss. As PACl enters the system, flocs are created. They then enter the filter and clog the pores between the sand thus increasing head loss. In the experiments conducted, data suggests that there is a linear increase in head loss until failure. This is demonstrated in the beginning of the experiments for higher dosages (slide with head loss zoomed in).

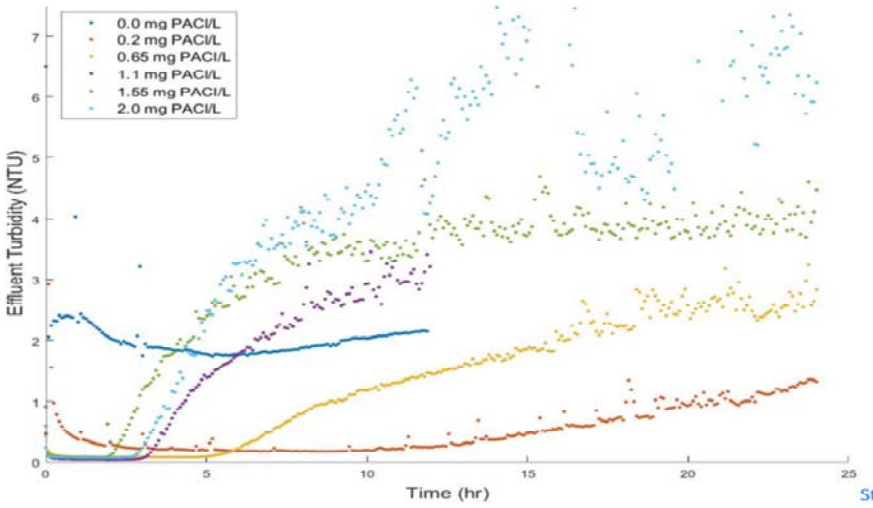


This graph compiles the curves for head loss in the same six experiments over its total 24 hour experiment time. For the experiments that did fail, the head loss curves converge on the same trend after failure. A theory we are considering is that there is an equilibrium floc size at which the rate of change in head loss after failure is no longer dependent on floc size and PACl dosage. Before failure, flocs are either broken up in the filter and flushed out the effluent or are trapped in the pores of the sand. However, after failure the size of flocs that are capable of going through the filter is eventually limited by shear forces in the sand column and pore size at which point there is an equilibrium floc size. Therefore experiments with PACl dosages greater than the PACl dosage associated with the equilibrium floc size will have various sizes of floc sizes, but will have the same effect on head loss so long as they are larger than the equilibrium floc size. We hypothesize that the flocs created in the 0.65 to 2.0 experiments are larger than the hypothetical equilibrium floc size thus head loss is affected very similarly in these experiments after failure and the curves converge on the same trend.

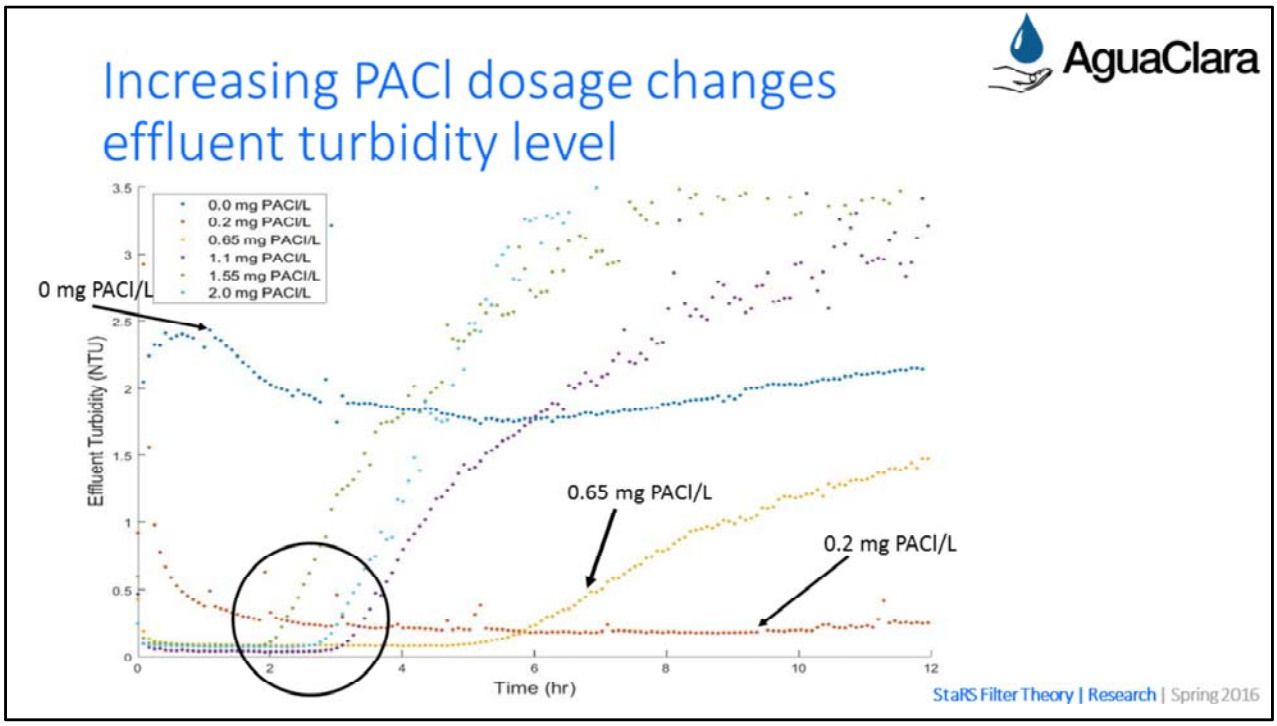


Further analyzing the head loss data, we graphed head loss vs mass of PACl added. Interestingly enough these curves do not converge. While we are still exploring for an explanation, these results may suggest that head loss is heavily affected by the rate of PACl going into the filter as opposed to the total mass of PACl entering the filter.

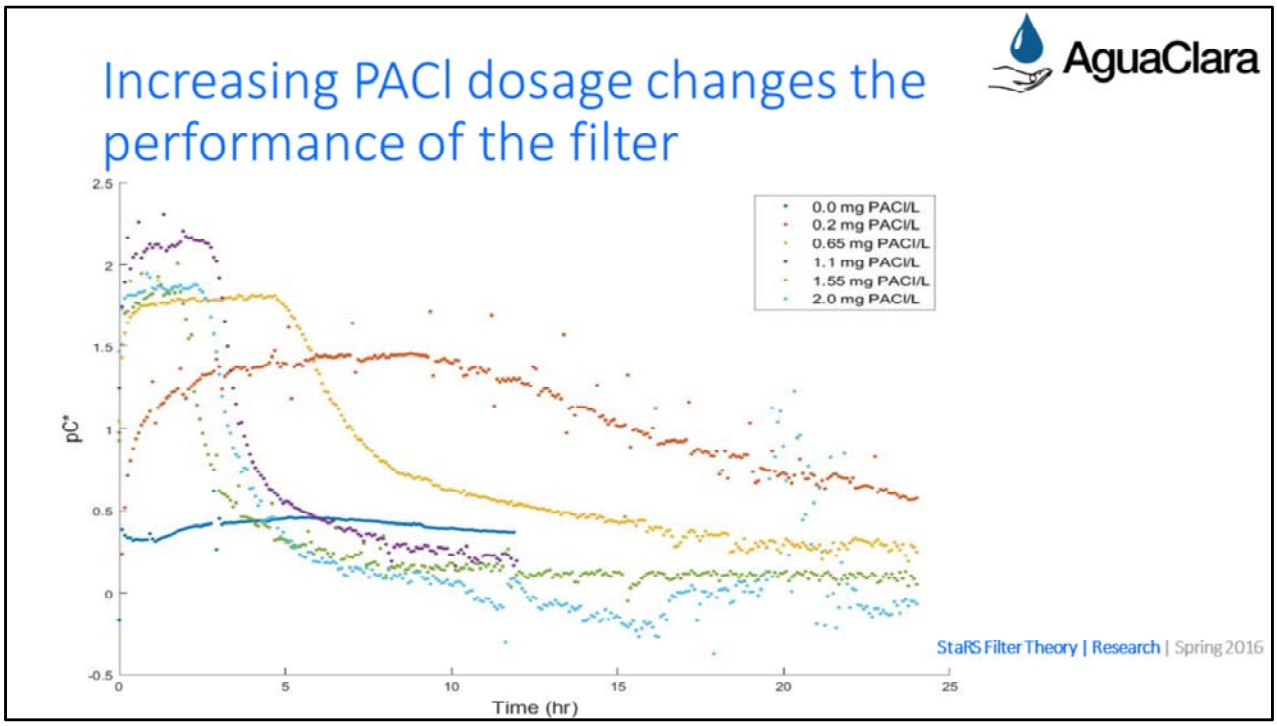
Increasing PACl dosage changes effluent turbidity level



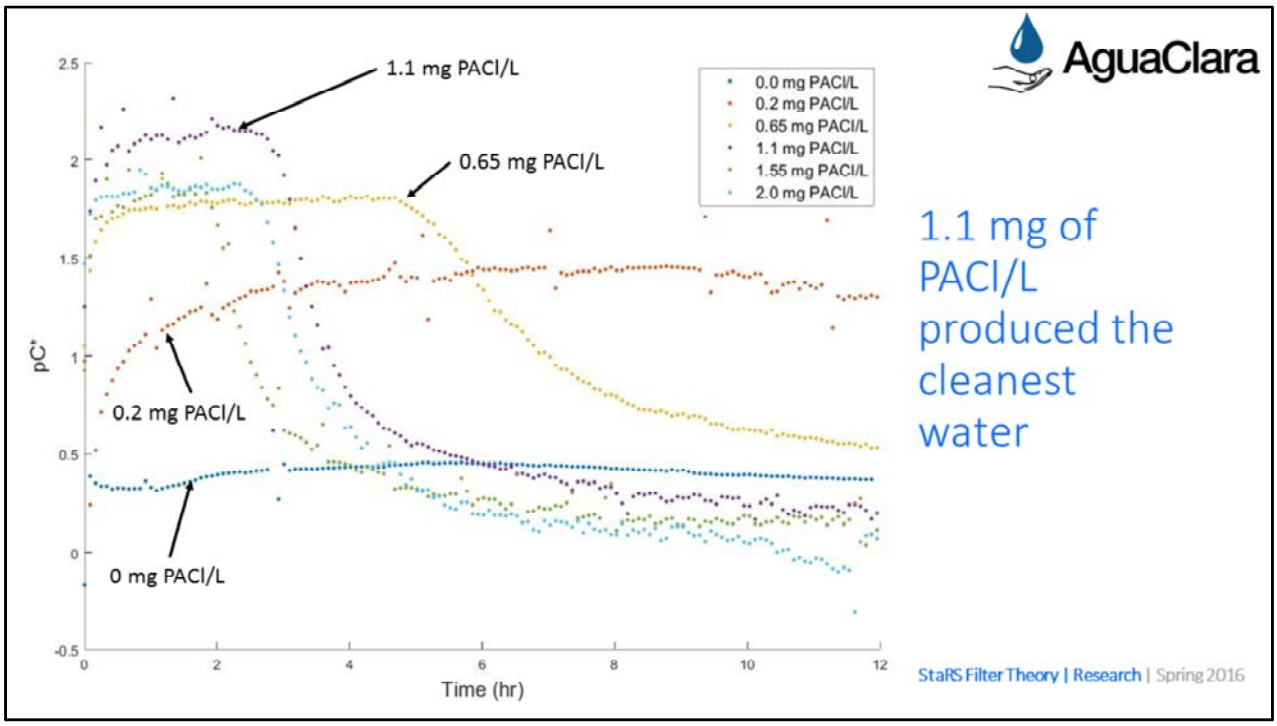
Jonathan



Jonathan
Here is a zoomed in look at the effluent turbidity that looks at the first 12 hours of filtration
-0 was a control experiment
Without PACl, the filter immediately failed.
As PACl was added, it decreased the effluent turbidity
As more PACl is added, the filter began to fail quicker
After 24 hours of filtration, the 0.2 mg PACl/L failed after 10 hours
After about 6 hours of filtration, the 0.65 mg PACl/L failed
1.1, 1.55, 2.0 mg PACl/L all failed in under 4 hours


Increasing PACl dosage changes the performance of the filter
AguaClara
0.0 mg PACl/L
0.2 mg PACl/L
0.65 mg PACl/L
1.1 mg PACl/L
1.55 mg PACl/L
2.0 mg PACl/L
pC*
Time (hr)
StaRS Filter Theory | Research | Spring 2016

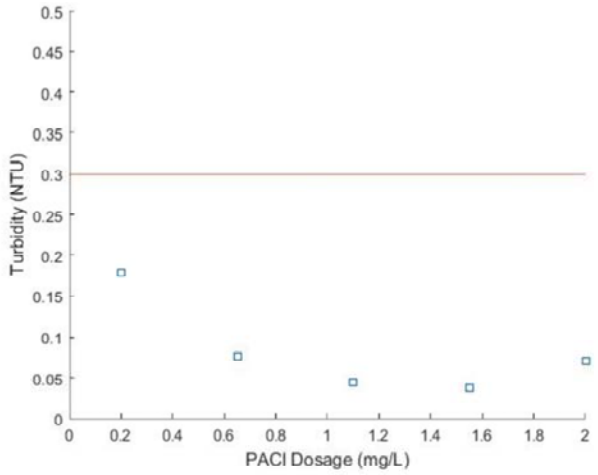
Jonathan



Jonathan
pC* shows the performance of our filter
pC* = -log(Effluent Turbidity/Influent Turbidity)

1.1 mg PACl/L produced the cleanest water
Even though the 0.2 mg PACl/L took the longest to fail, the quality of water was not as good as the higher PACl dosages
1.55 and 2.0 mg PACl/L both produced similar quality water, however the 1.55 failed in our experiments before 2.0
The 0.65 mg PACl/L produced water that is very close to both 1.55 and 2.0 mg PACl/L

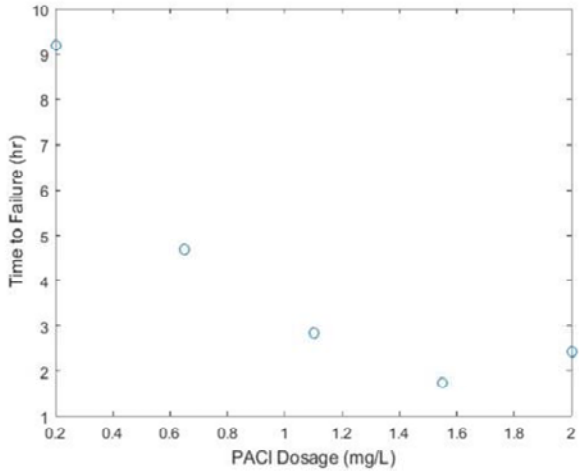
Increasing PACl dosage results in varying effluent turbidities



Theresa
Plot of cleanest effluent turbidity before the filter failed (not just a peak, but representative of average effluent turbidity)
Everything is below US EPA standard, so the filter is doing well
Trade off between filter run time, coagulant dosage, and effluent turbidity
More coagulant doesn't result in lower turbidity

AguaClara

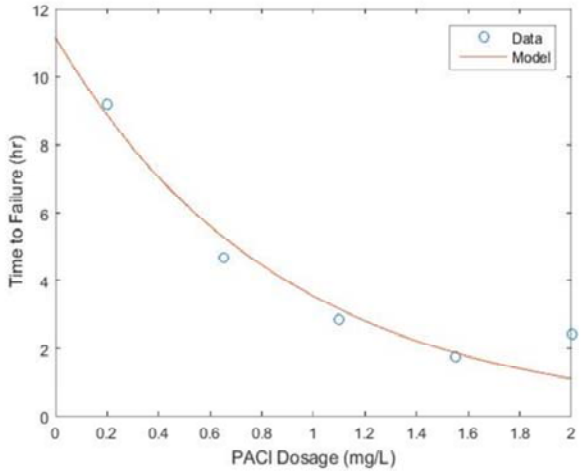
Increasing PACl dosage causes faster failure



Theresa
Failure times

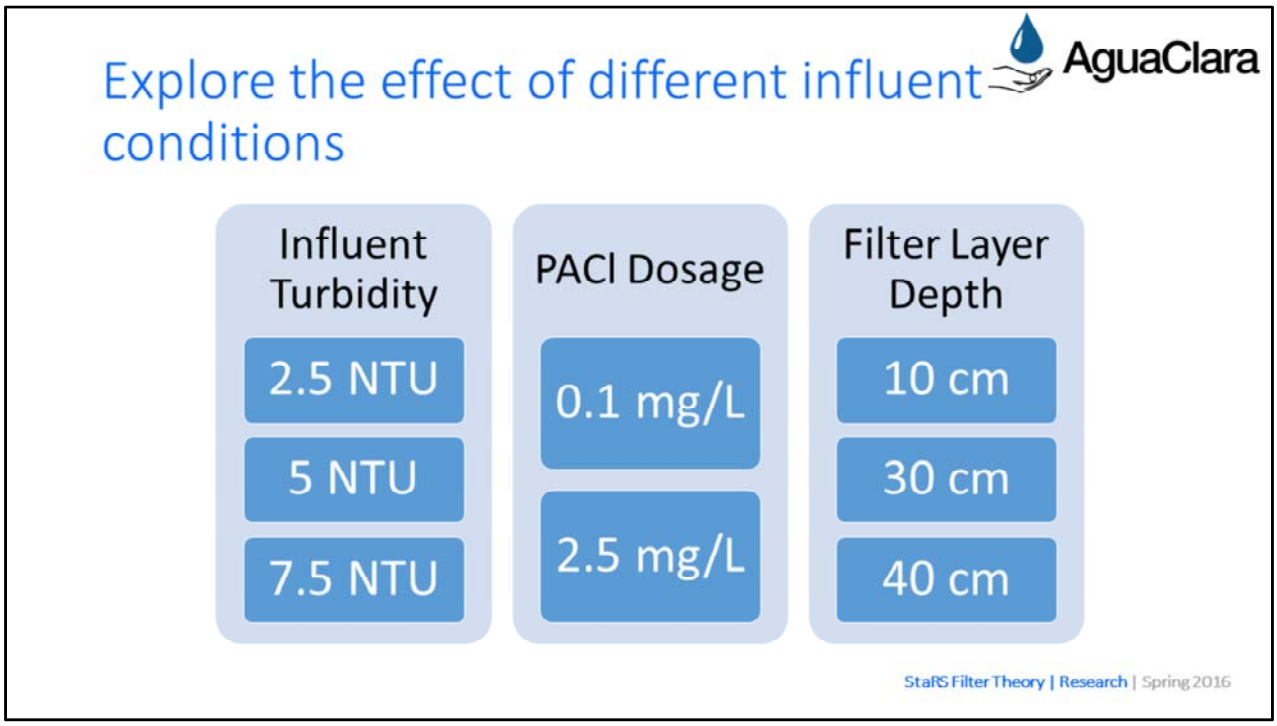
AguaClara

Increasing PACl dosage causes faster failure

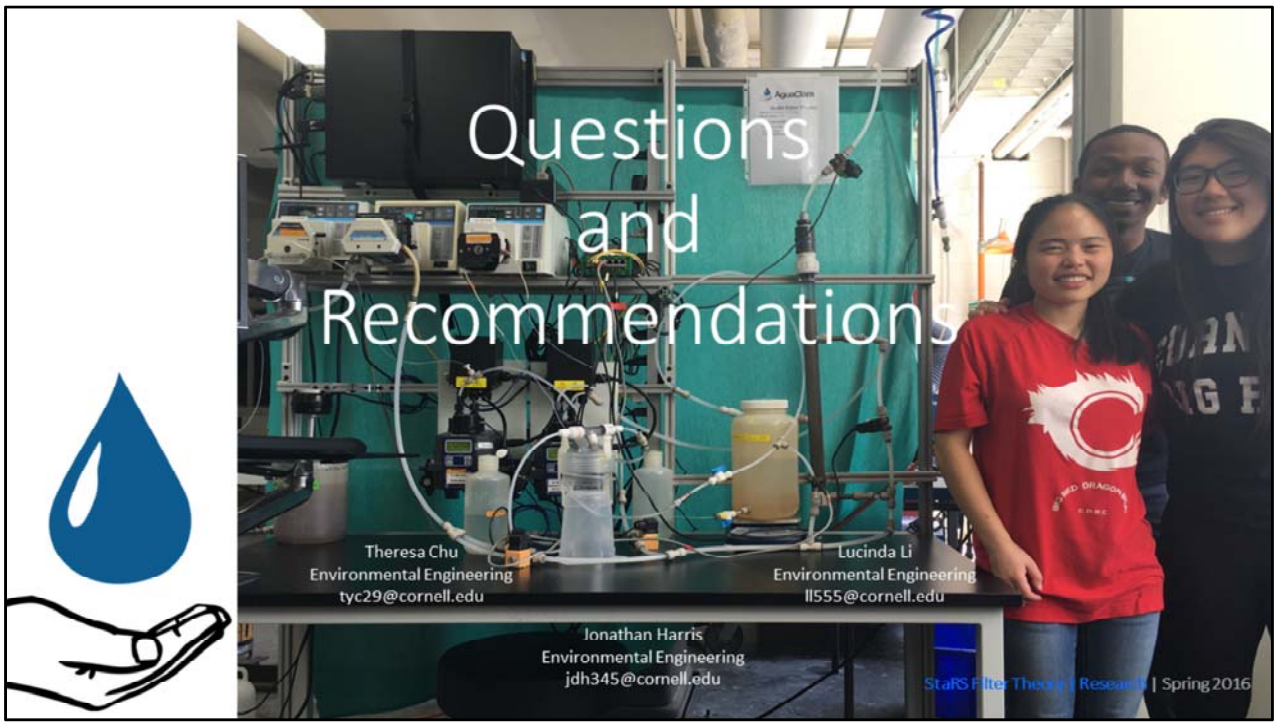


StaRS Filter Theory | Research | Spring 2016

Theresa
Fitted an exponential model to failure times
Decrease in time to failure with increased coagulant dosage
Why? Mass increase in filter leads to higher head loss, pores clogging, fractal flocs



Theresa
Coagulant sticks to walls of filter, making backwash difficult
Flocs settles in cuvette of turbidimeter measuring influent water
2.5, 5, 7.5 NTU
Lower and higher PACl dosages
Data analysis

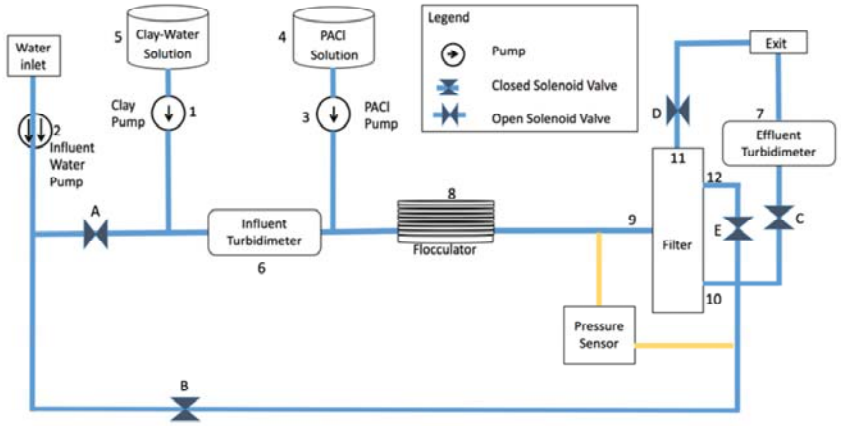


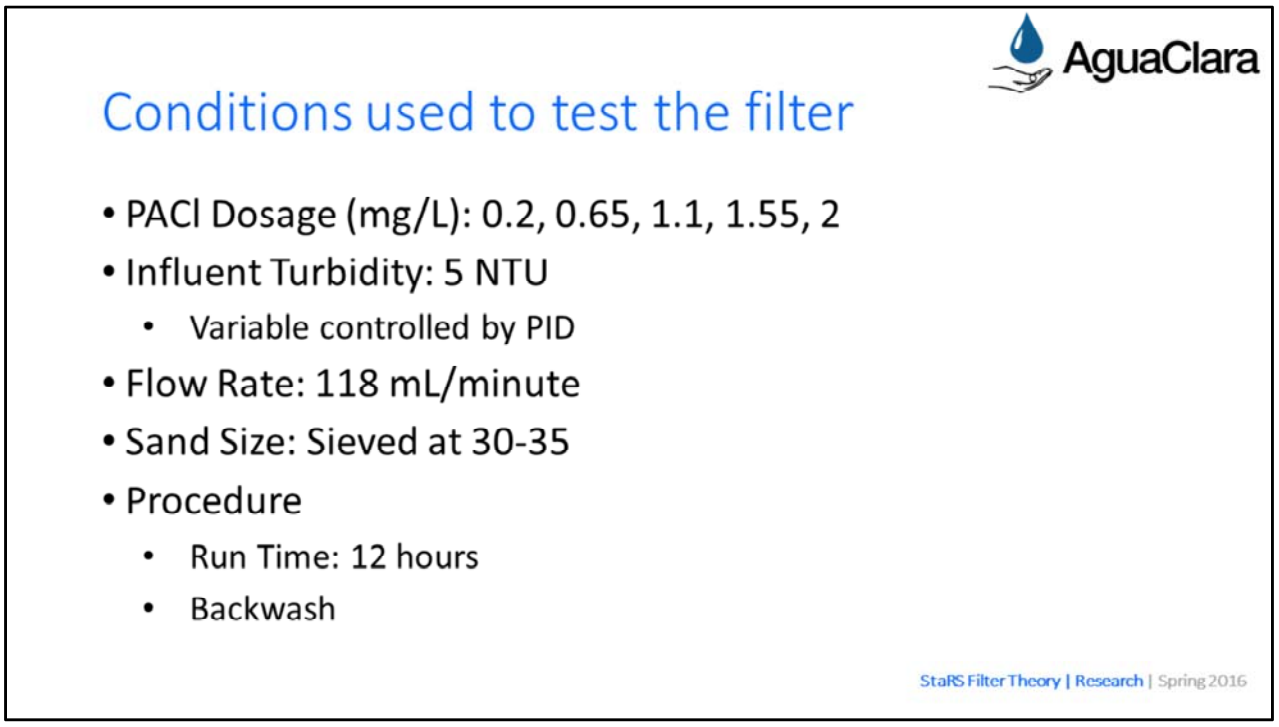
Theresa | Environmental Engineering ‘16 | tyc29@cornell.edu
Lucinda | Environmental Engineering ‘18 | ll555@cornell.edu
Jonathan | Environmental Engineering ‘19 | jdh345@cornell.edu

AguaClara

Appendix Slides

Filter Schematic





Procedure and experimental conditions
PID