The 2nd Annual WIN Workshop
Brackish Groundwater National Desalination Research Facility (BGNDRF)
October 28-29, 2019

Photobiological Treatment of Brackish Water and Wastewater

- Applications in RO Brine Management -

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Acknowledgements

- Bureau of Reclamation (Pitch-to-Pilot, R17AC00036)
  - Denver Office
  - BGNDRF
- Pacific Advanced Civil Engineering (PACE)
- University of Arizona
- University of California, Riverside
- New Mexico State University
- Fukui Prefectural University
- Orange County Water District
- National Science Foundation (NSF)

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Brackish Water & Us

- Only 0.5% of water on the earth is readily available for us to use
- Brackish groundwater was identified as a potential source of water
  - Water Desalination Act on October 11, 1996
- Challenges
  - High cost
  - Constituents
- Calcium sulfate, calcium carbonate, silica
- Construction of BGNDRF completed in August 2007

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Types of Brackish Water

- Groundwater
- Surface water
- Recycled water

https://www.youtube.com/watch?v=mKxkZ3n_0rA

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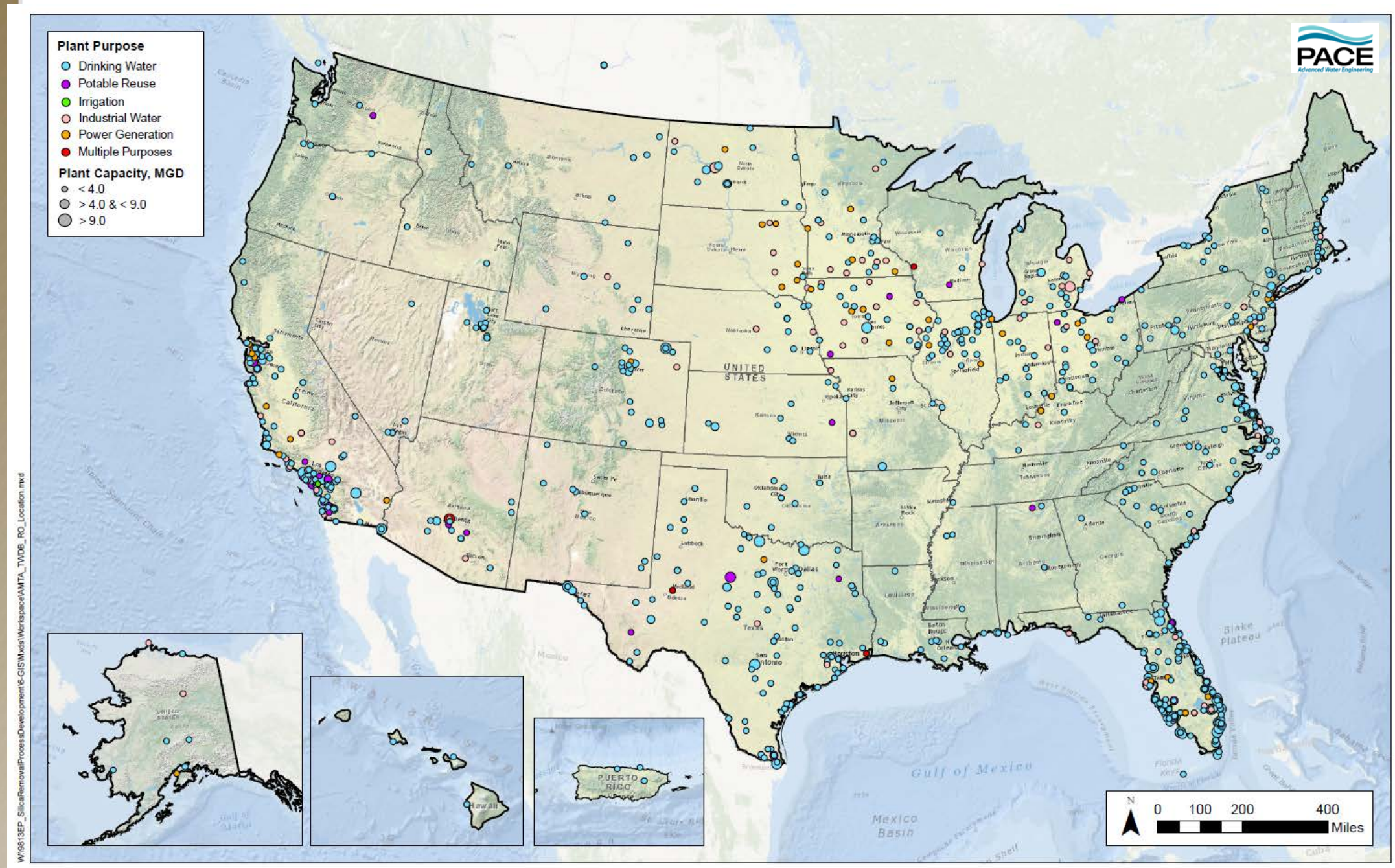
https://www.youtube.com/watch?v=mKxkZ3n_0rA



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RO Concentrate Management

- Current disposal methods
  - Ocean/surface water discharge
  - WWTP
  - Deep well injection
  - Evaporation ponds
- Challenges
  - Cost (as much as $0.5 M per year)
  - Environmental impact
    - High salt, organic, nutrient content, CECs
  - Scaling in the pipeline
- Higher recovery is desirable
  - Adding 3rd stage or 4th stage RO
  - Limiting factors
    - $CaSO_4$, $CaCO_3$, SiO_2

$1.30 per 1,000 gallons!

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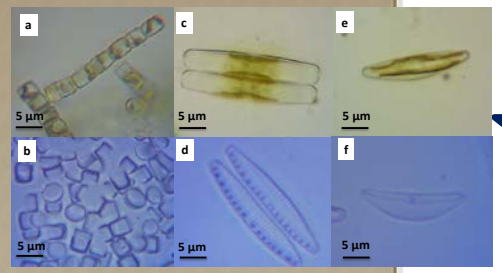
Feed Water
(Recycled Water/
Brackish
Groundwater)

Fresh Water
(75% to 85%)

Brine
(15% to 25%)

Existing 2- or 3-Stage RO

>95%
Overall
Fresh Water
Recovery



Additional
Fresh Water
(10% to 20%)

Diatom
Photobioreactor

Secondary RO

Final Brine
(<5%)

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Ikehata et al. (2017) *Journal of Applied Phycology* 29: 223-233.
Ikehata et al. (2018) *Water Science & Technology: Water Supply* 18(2): 594-602.

BGNDRF Pitch to Pilot Study

- **Our bench-scale study demonstrated…**
  - Applicability of photobiological treatment to RO concentrate samples from different RO facilities (10 out of 12)
  - Efficient removal of dissolved silica, as well as calcium carbonate, nutrients, and other constituents
  - Most of the work to-date focused on AWPF RO concentrate
- **Objective**
  - To demonstrate the feasibility of our photobiological treatment technology to achieve high (>90%) water recovery from brackish groundwater using a 1,500-gallon pilot-scale reactor at the BGNDRF
  - To learn the impacts of different water quality parameters and environmental factors

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Lab-scale Experiments

- Reactors
  - 50-mL clear centrifuge tubes
  - 2-gallon HDPE buckets
    - Working volume: 1 gallon
- Light sources
  - 9-W LED bulbs
  - Natural sunlight
- Nutrients
  - F/2 (nitrate, phosphate, vitamins, trace minerals)
  - Sodium nitrate
  - Ammonium sulfate
  - Sodium phosphate monobasic
- Static, aeration mixing, carbon dioxide addition
- Batch- and semi-batch modes
- Diatom strain: *Pseudostaurosira trainorii* PEWL001

50-mL Reactors (Indoors)

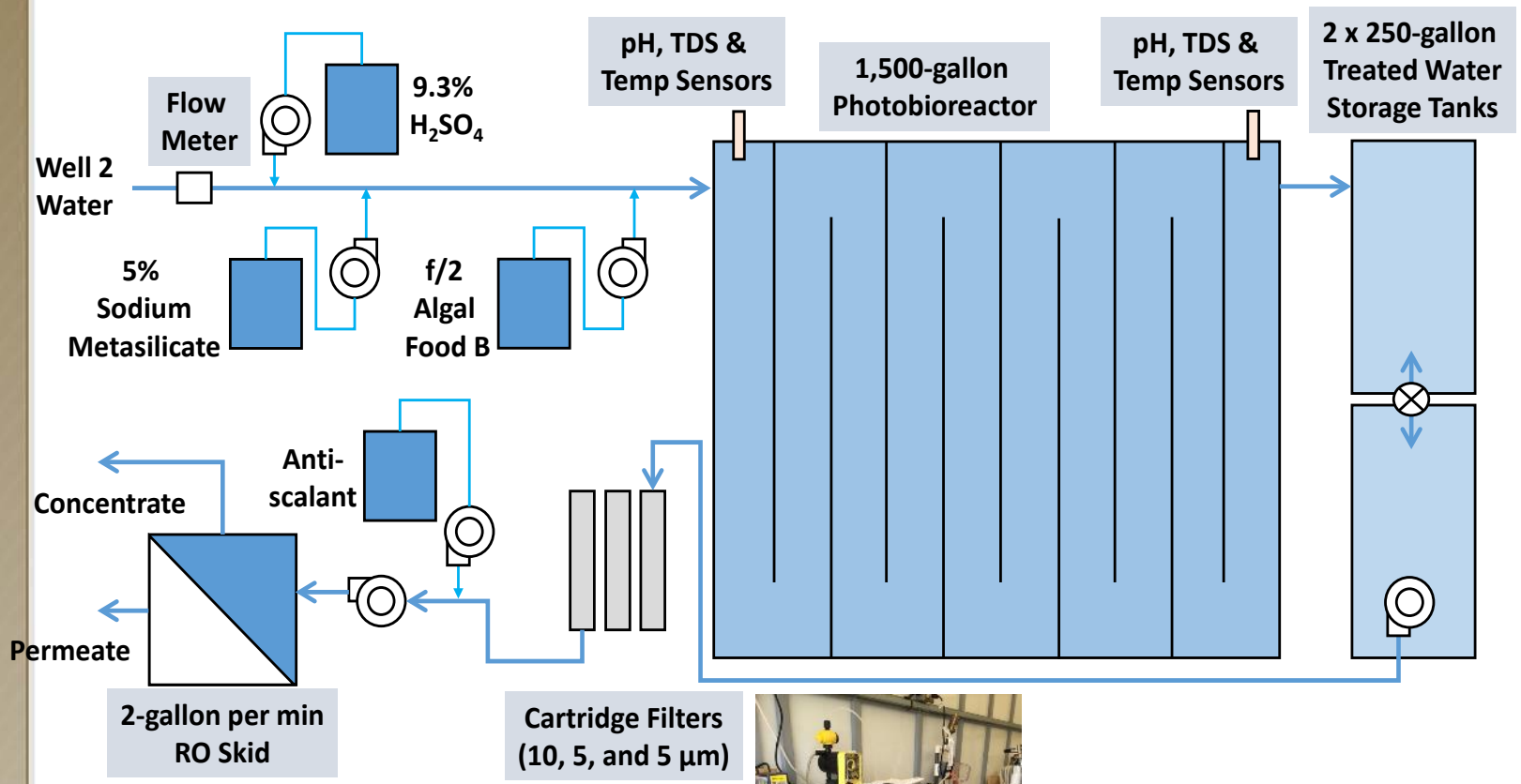
3.8-L Reactors (Indoors)

3.8-L Reactors (Indoors)

3.8-L Reactors (Outdoors)

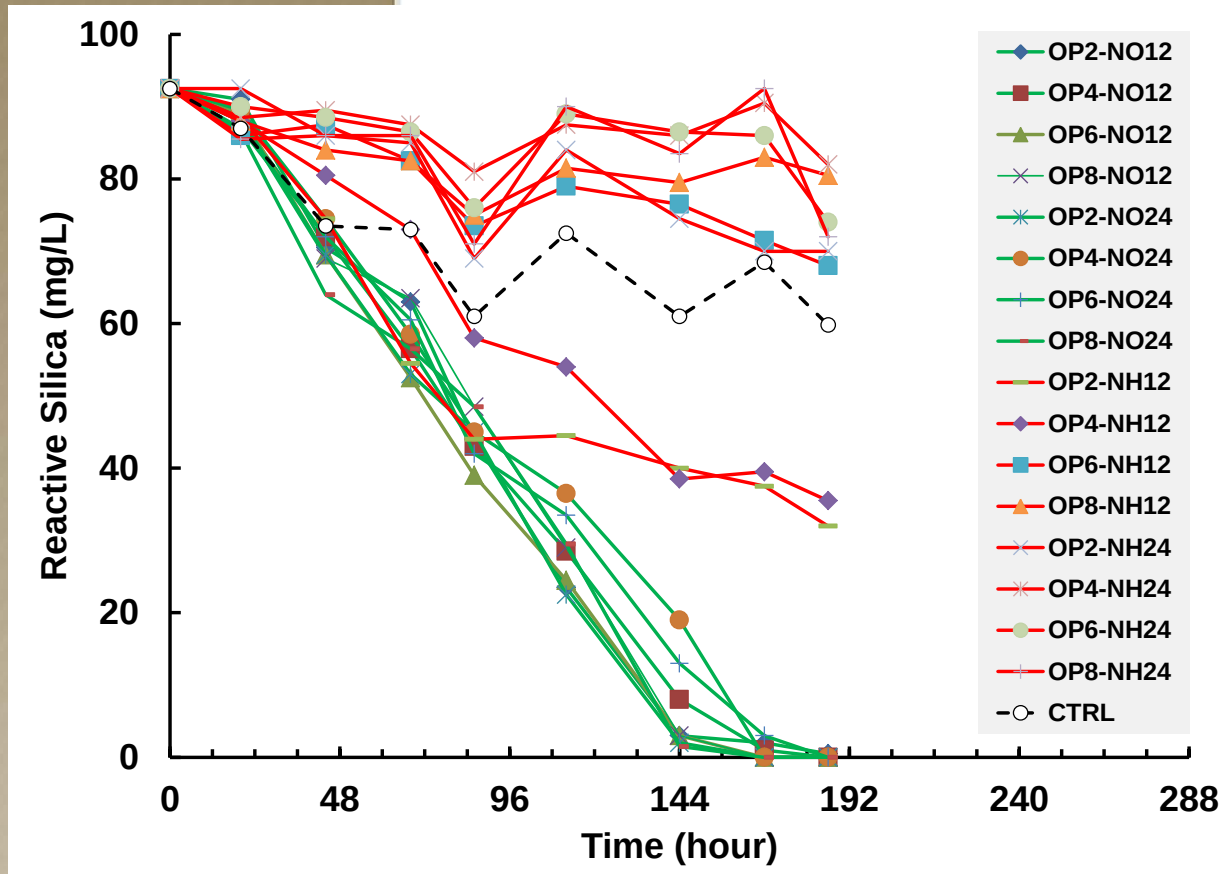
Kulkarni et al. (2019) *Desalination* 452: 114-122.

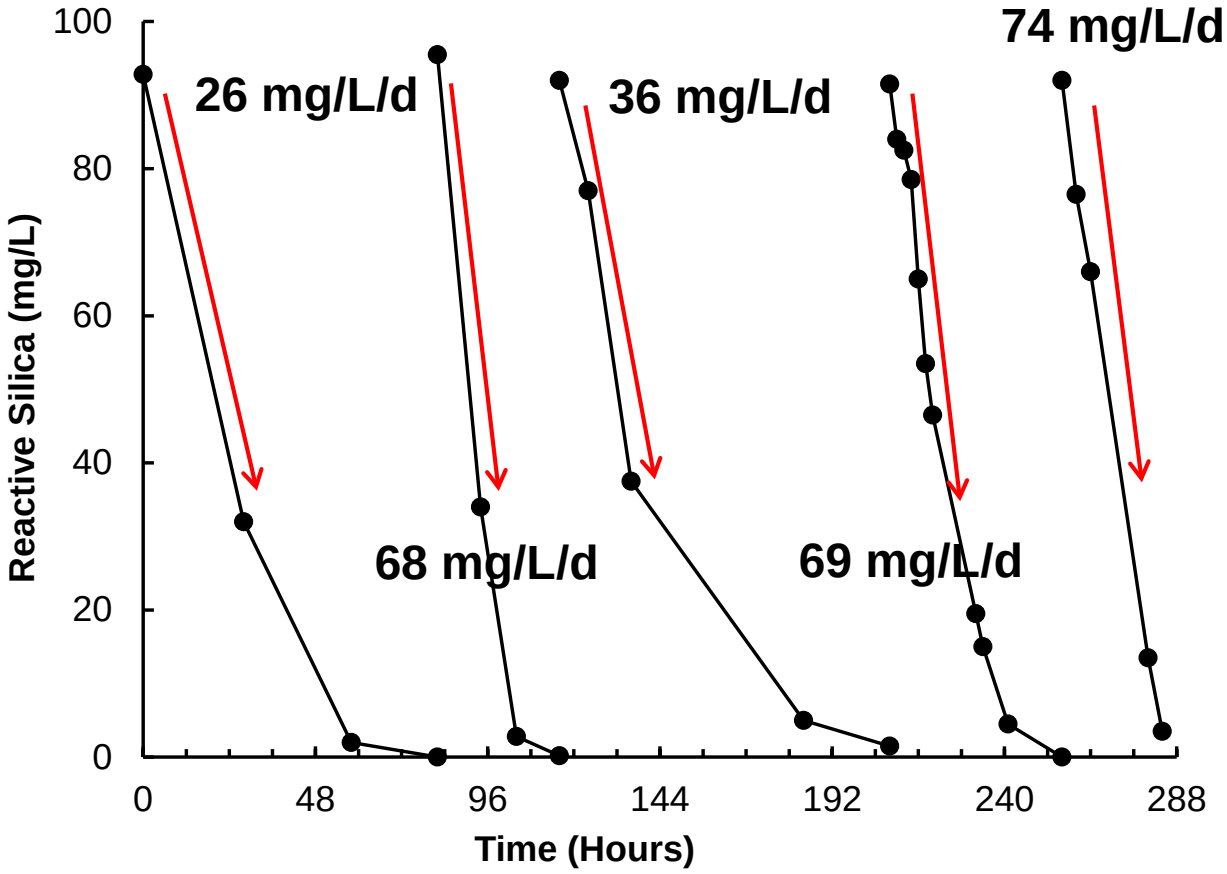
Pilot-scale Experiments



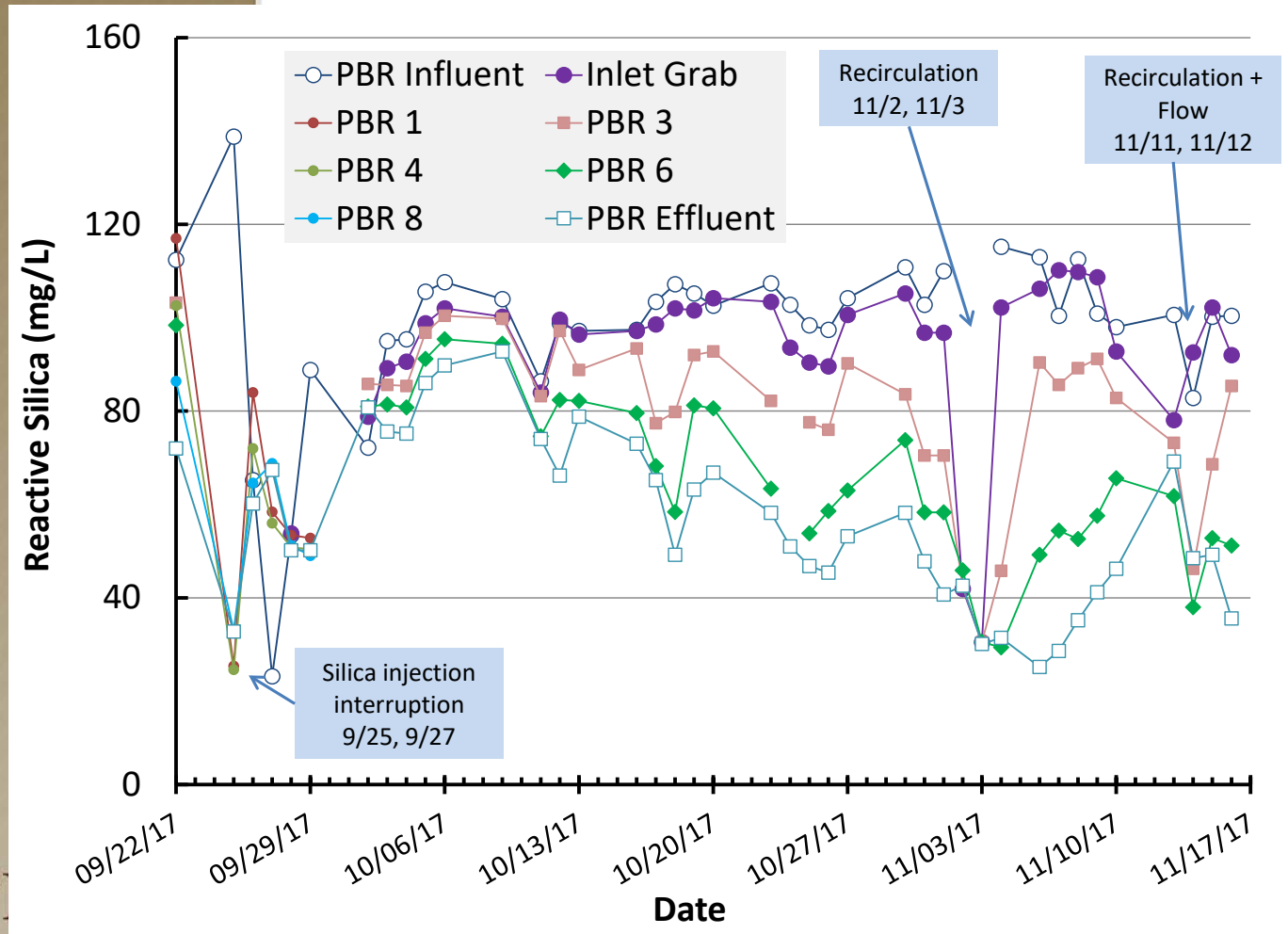
- **Outdoor (Test Pad 7 at BGNDRF)**
- **Continuous flow**

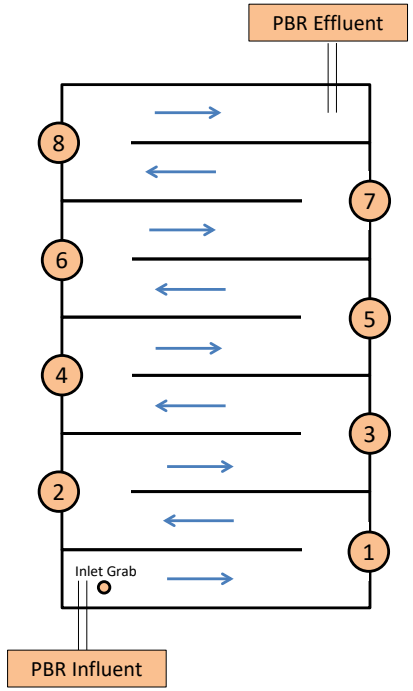
Results

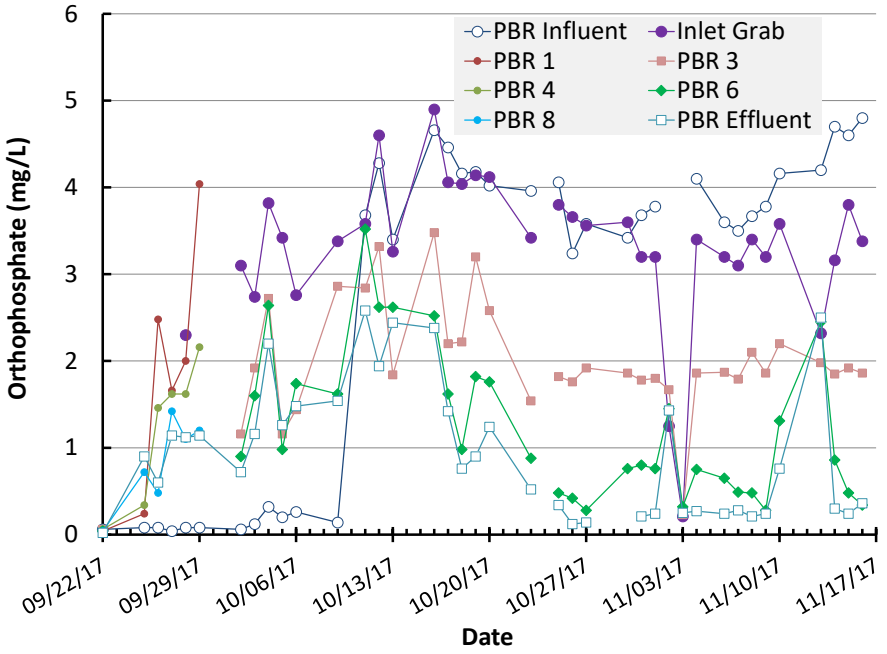




Kulkarni et al. (2019) *Desalination* 452: 114-122.

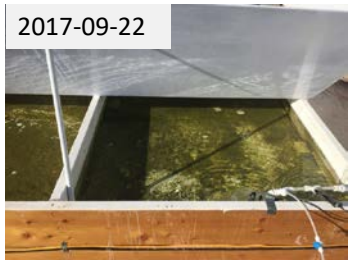

PBR Influent
Inlet Grab
PBR 1
PBR 3
PBR 4
PBR 6
PBR 8
PBR Effluent
Recirculation
11/2, 11/3
Recirculation +
Flow
11/11, 11/12
Silica injection
interruption
9/25, 9/27
Reactive Silica (mg/L)
160
120
80
40
0
09/22/17
09/29/17
10/06/17
10/13/17
10/20/17
10/27/17
11/03/17
11/10/17
11/17/17
Date


PBR Effluent
8
7
6
5
4
3
2
1
Inlet Grab
PBR Influent


PBR Influent
Inlet Grab
PBR 1
PBR 3
PBR 4
PBR 6
PBR 8
PBR Effluent
Orthophosphate (mg/L)
6
5
4
3
2
1
0
09/22/17
09/29/17
10/06/17
10/13/17
10/20/17
10/27/17
11/03/17
11/10/17
11/17/17
Date


8/17/2017
Last 2 baffles towards the end of the PBR
These baffles were not inoculated


8/18/2017
First baffle biomass


2017-09-22


2017-09-25


2017-09-26

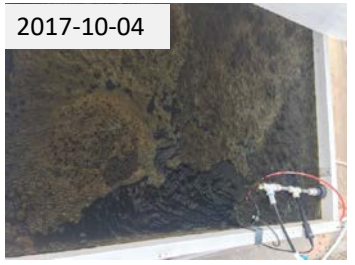

2017-09-27

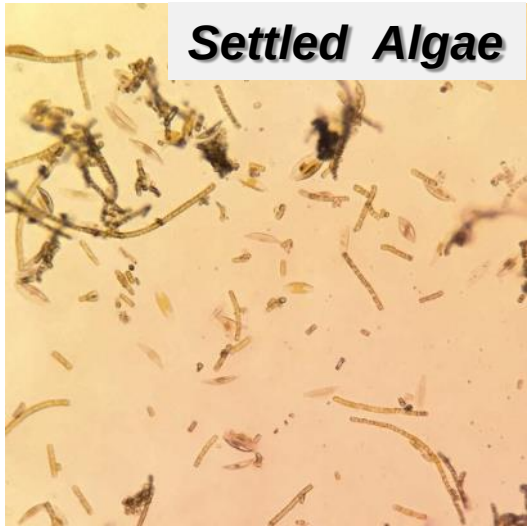

2017-09-28

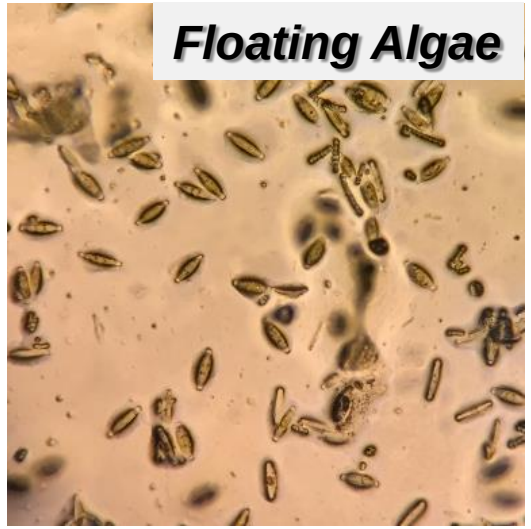

2017-09-29


2017-10-02

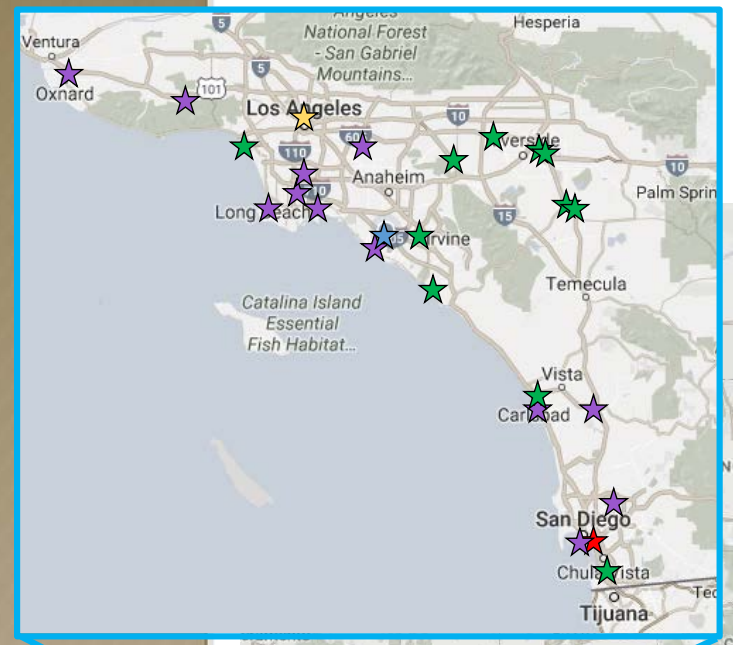

2017-10-03

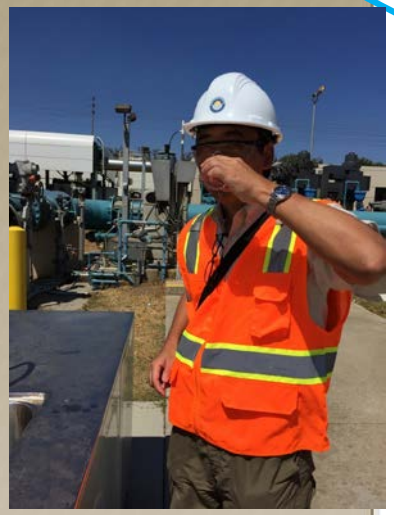

2017-10-04


Settled Algae


Floating Algae

NSF SBIR Phase I



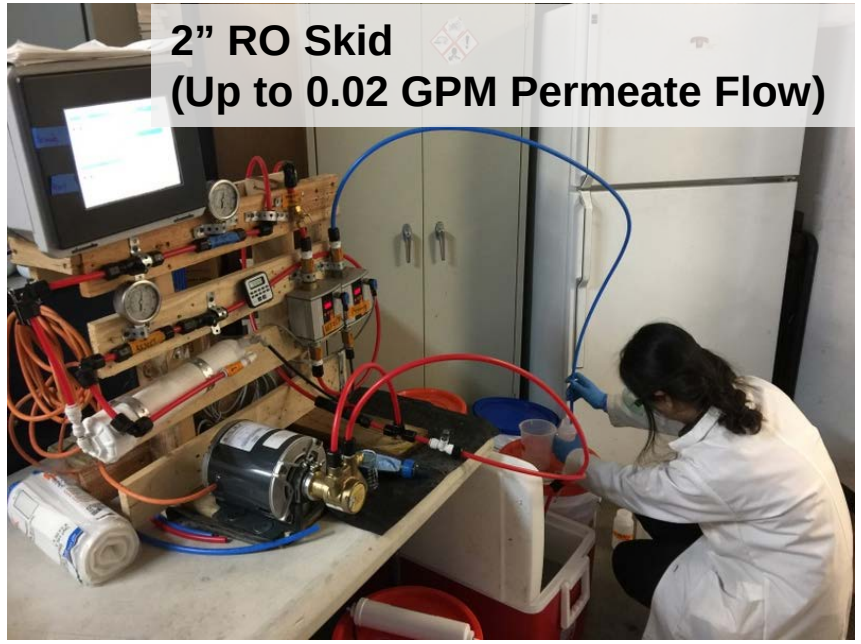


- PACE
- IPR/DPR
- BGWRO
- Non-potable
- Surface Water
- Funding Source
- Regulator
- Expert

Ikehata et al. (2019) *Water Supply* 19(6): 1661-1667.

15-Gallon Photobioreactor (Outdoors)

2” RO Skid
(Up to 0.02 GPM Permeate Flow)



2-Gallon Buckets (Outdoors)

2.5” x 40” x 5 RO Skid
(Up to 1 GPM Permeate Flow)

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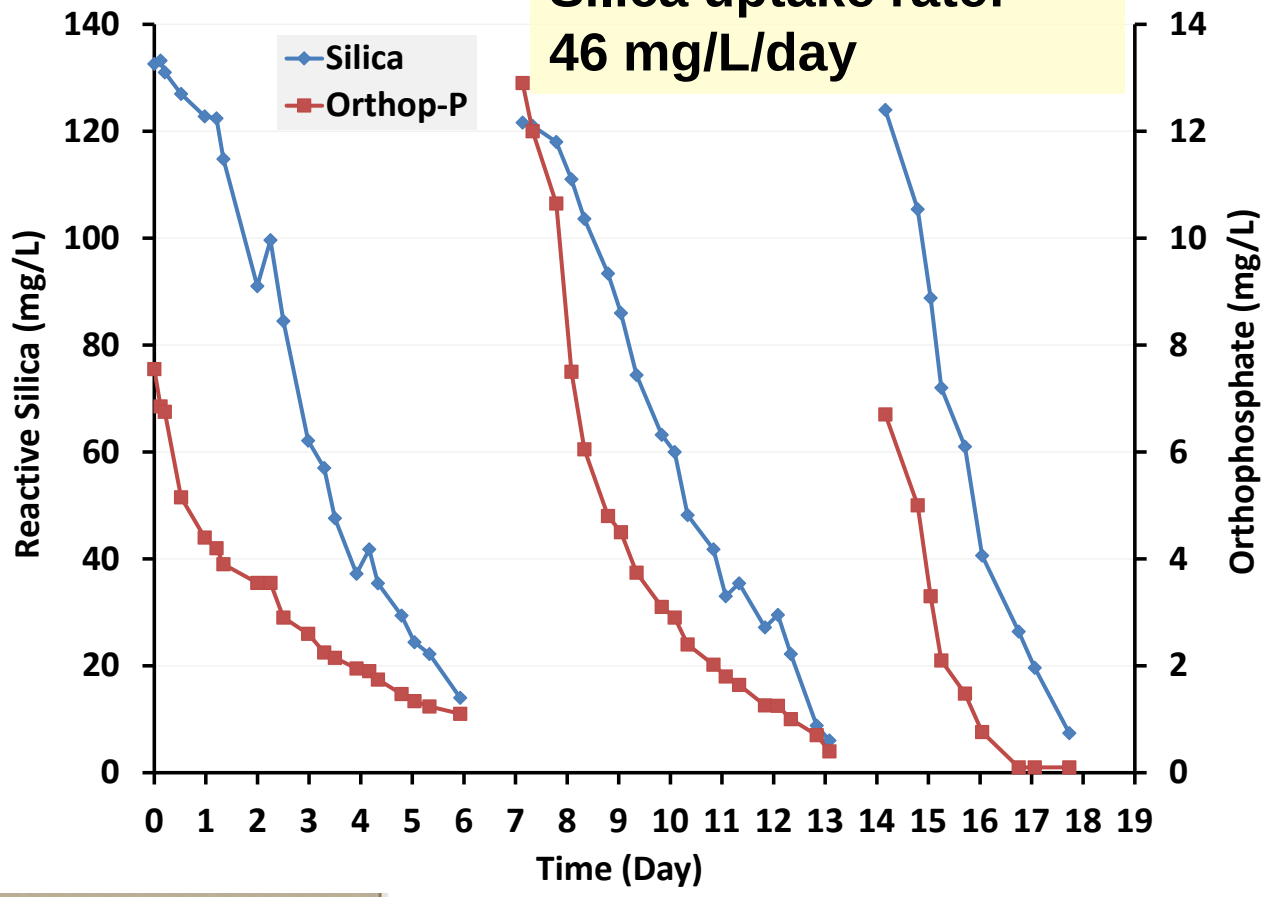
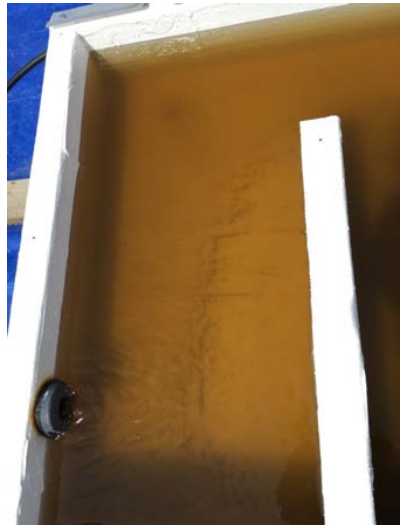
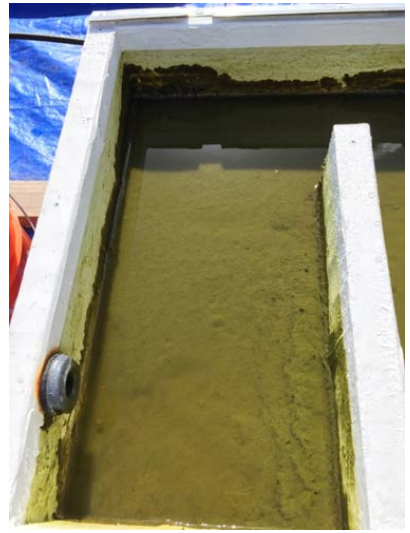
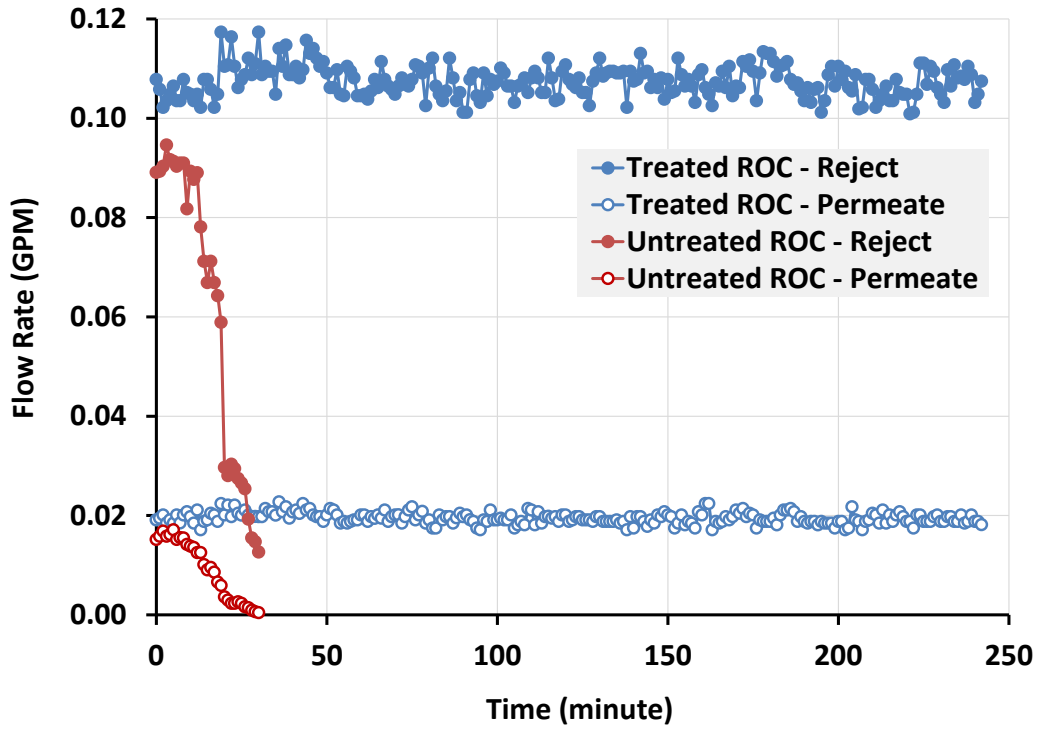
Silica uptake rate:
46 mg/L/day





19 Days





Ikehata et al. (2019) *Environmental Science & Technology* 52(12): 8588-5295.

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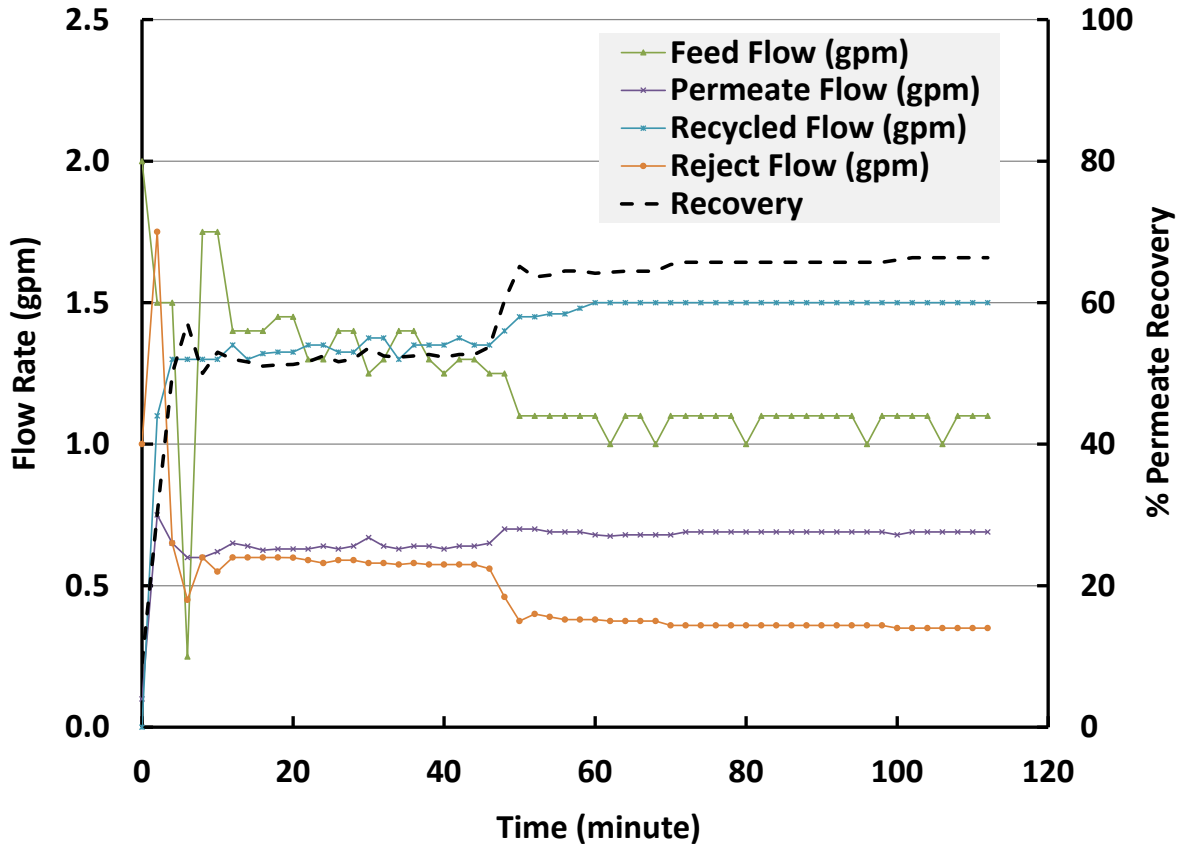
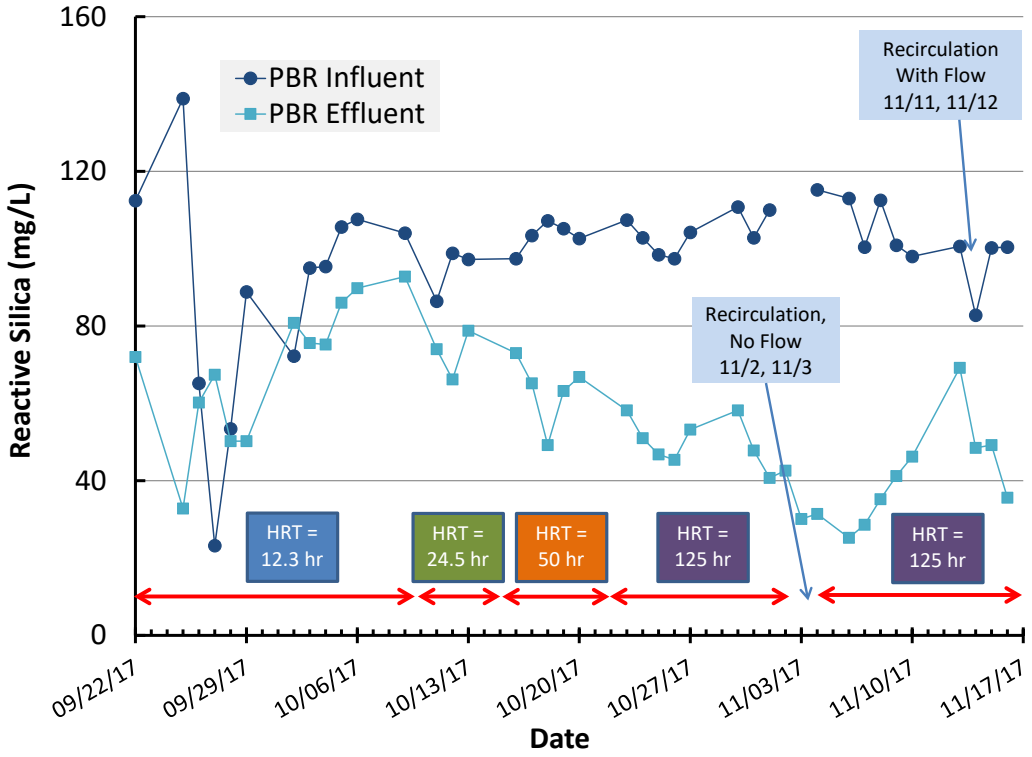


66% Recovery

Primary RO Permeate Recovery 85% + **Secondary RO Permeate Recovery 15% x 66% = 10%** = **95% Overall Permeate Recovery**

Major Conclusions

- A wide applicability (>10 facilities)
- >95% overall permeate recovery
- Up to 74 mg/L/day reactive silica uptake
- 15-gallon rooftop pilot photobioreactor
- 1,500-gallon pilot-scale photobioreactor
  - Silica removal was slower



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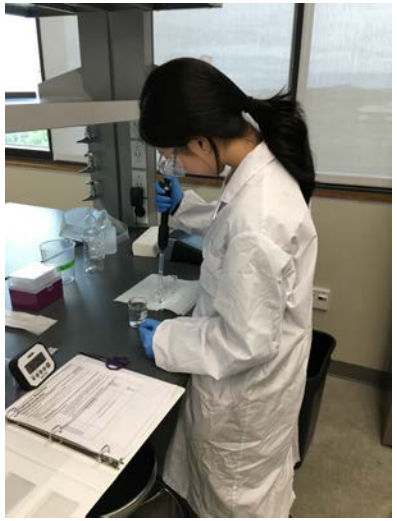
On-going Works

- Challenges
  - Long HRT, contamination & long-term operation
- On-going research
  - Contamination control
  - Treatment optimization
    - Additional diatom isolation and screening
      - Mixed culture diatoms vs. pure culture
    - RO concentrate from Western and Central Texas
    - Impact of temperature, light intensity, and wavelength
    - Reactor hydraulics
  - Beneficial use of algal biomass
  - Lifecycle cost analysis
  - Smaller pilot study



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Thank You!

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