On-site Greenhouse Ecosystem to Treat Craft Beverage Wastewater

NOWRA Onsite Wastewater Mega-Conference

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Carley Allison and Steven Safferman

Department of Biosystems and Agricultural Engineering

Michigan State University

alliso68@msu.edu, SteveS@msu.edu

The materials presented represent our own opinions and do not reflect the opinions of NOWRA

Craft Beverage Overview

- High strength wastewater
  - High oxygen demands
  - High nutrients
- Hard to treat
  - Varying flow
  - Varying composition
- In Michigan
  - 90+ cideries
  - 200+ wineries
  - 300+ breweries

https://www.michigan.gov/mdard/about/boards/craftbeverage

What is a Greenhouse Ecosystem?

- Uses native plants to treat wastewater
  - Long roots
  - Have shown to treat wastewater
  - Native plants
- Examples:
  - Cattail
  - American Sweetgrass
  - Duckweed
  - Swamp loosestrife
  - Three-square bulrush
- Greenhouse for treatment over winter

https://www.minnesotawildflowers.info/flower/swamp-loosestrife

Successful Examples

- South Burlington, VT
  - Sewage in cold climates
- Oberlin College, OH
  - Municipal wastewater from dorms
- Frederick, MD
  - Untreated raw sewage
- And many more!

J. Todd et al. Ecological Engineering 20 (2003) 421-440)

https://www.oberlin.edu/ajlc/building-systems/living-machine

https://www.buildinggreen.com/feature/ecological-wastewater-treatment

General Craft Beverage Wastewater Characteristics

Parameter (mg/L)	Winery	Brewery	Cidery
Chemical oxygen demand (COD)	3,236	11,214	>100,000
Biochemical oxygen demand (BOD)	2,046	2,746	4,800
pH	6.2	6.74	N/A
Sodium	279	N/A	N/A
Total solids	N/A	5,600 (TSS)	N/A
Total phosphorous (TP)	5.26	16-68	N/A
Total Nitrogen (TN)	7.6	12-31	N/A

Design

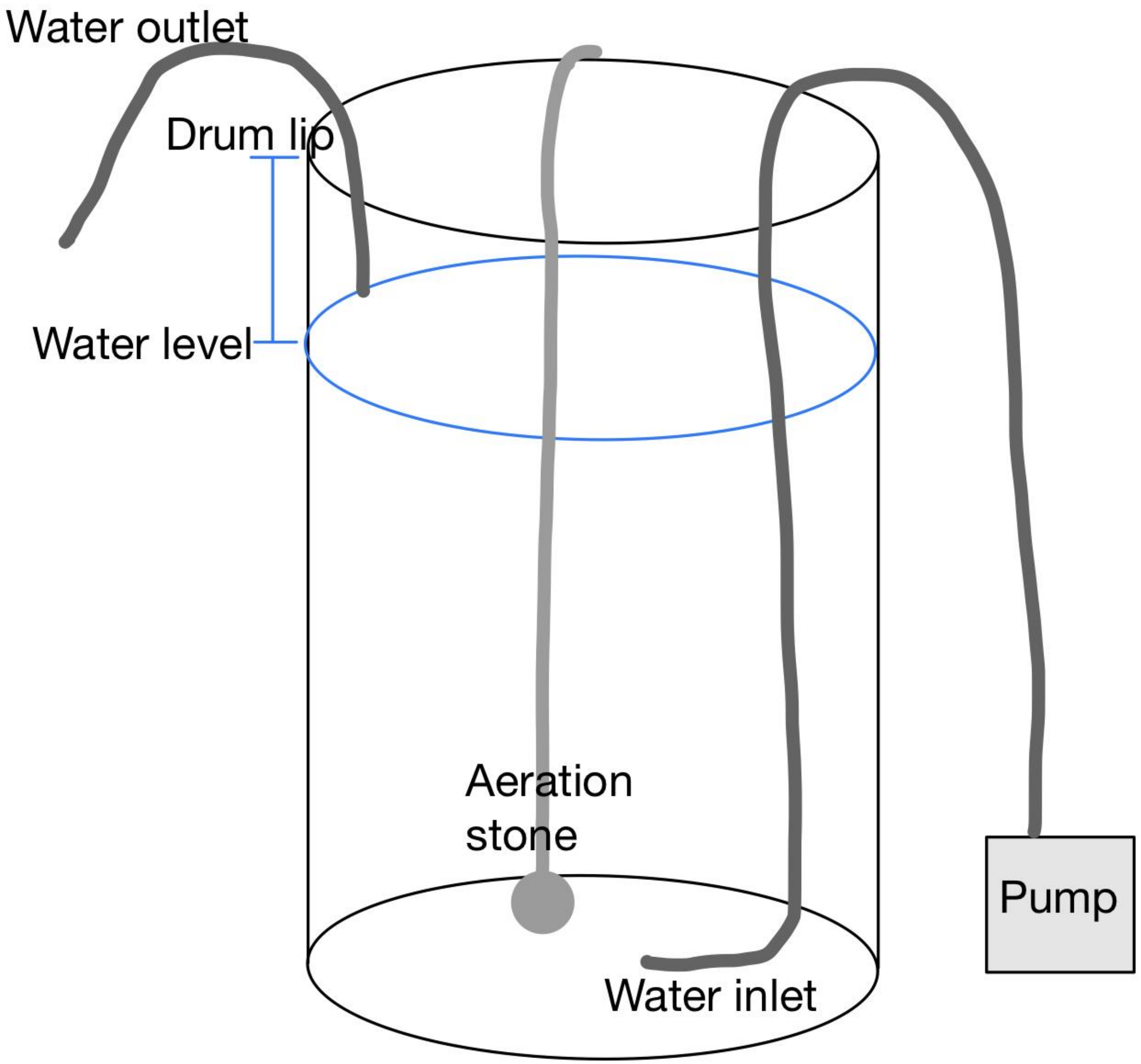
- Choose organic and hydraulic loadings.
- Select native plants well suited for this application of plants.
- Designed frame height to anchor grow lights based on cattails since these are the tallest plants.
- Determined diameter and depth of containment based on plant root growth.
- Used refrigerator to store wastewater
- Based synthetic wastewater on the composition of actual wastewater

Flow and Loading

- Literature review – collected hydraulic residence times and loadings.
- Repeated calculations using the below variables to determine the optimal volume and flow.
  - Average loading
  - Changing reactor volumes
  - Changing flow rates

System Components

- Loading: 0.61 kg/m2/d
- Volume: 50 gallons, using a 55-gallon drum
- Flowrate: 5.4 gal/d
- Pumps/lights/aeration – 12-hour cycle



Plants

- Cold tolerant
- Pruning ability
- Native to Michigan
- Non-invasive in the US
- Root Depth

Greater duckweed

American Sweetflag

Swamp loosestrife

Three-square Bulrush

Cattail


ALUMNI

Goals

- Determine treatment ability through the train
- Determine treatment ability for different variables
  - High COD
  - High nutrients
  - High COD and nutrients
  - High nutrients and salt
- Proof of concept study, not optimization

Methods

- Daily pH and dissolved oxygen readings
- Weekly nitrate, nitrite, ammonia, total nitrogen, total phosphorous, and chemical oxygen demand.
- Quality assurance and quality control:
  - Blank
  - 3 replicates
  - Standard

Phases

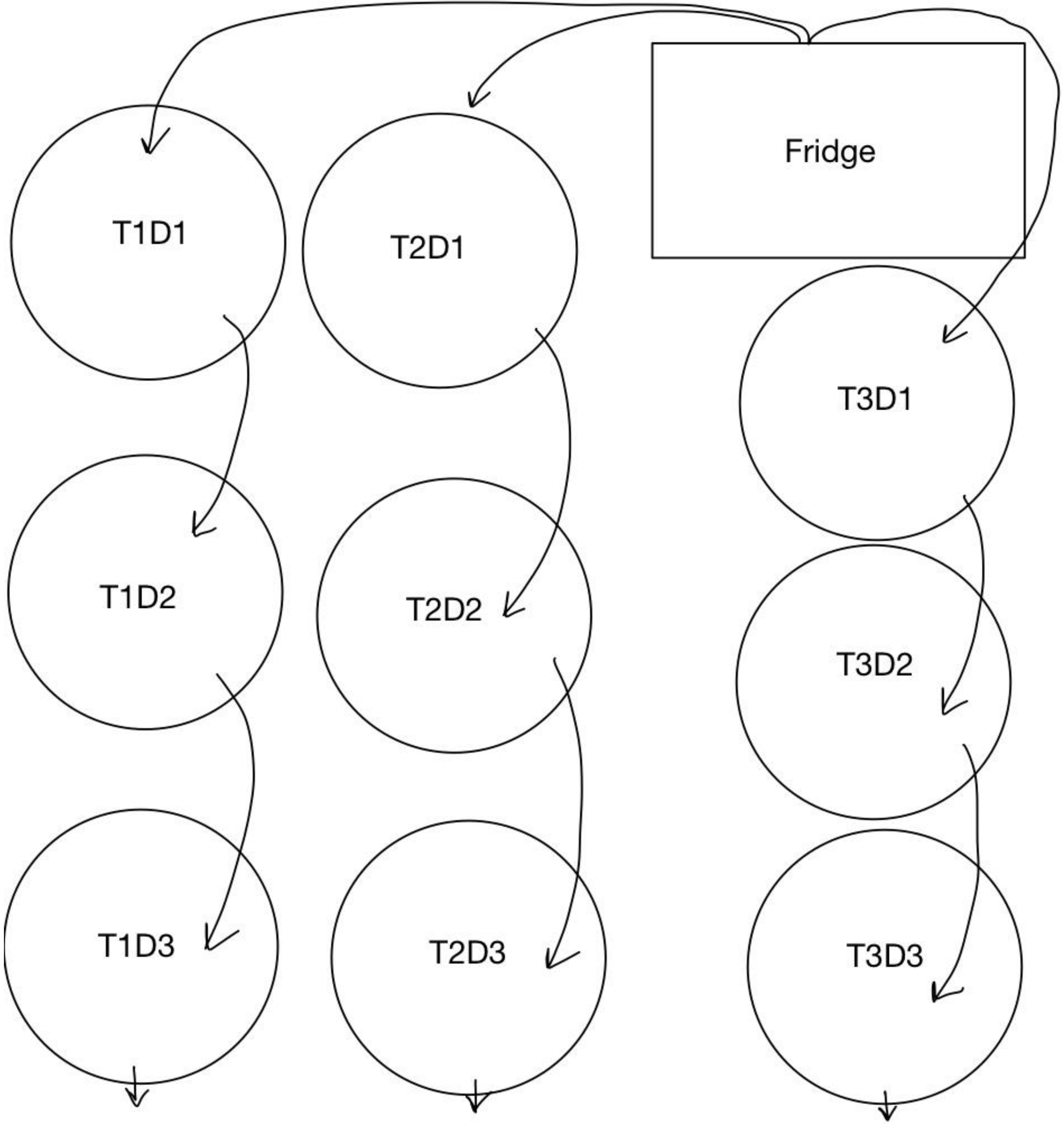
Date	3/20	4/6	4/20	5/17	5/31	6/22	7/14	8/25	8/30	9/20
Start up										
High COD (T2)										
High nutrients (T3)										
High COD + nutrients (T2)										
High nutrients + salt (T3)										
Actual winery (T2)										
Actual Cidery (T3)										
No plants (T1)										
Actual Brewery (T2)										
Revive dead train (T3)										

Train 1 will be the control train for all series except the last one, where it will have the plants taken out.

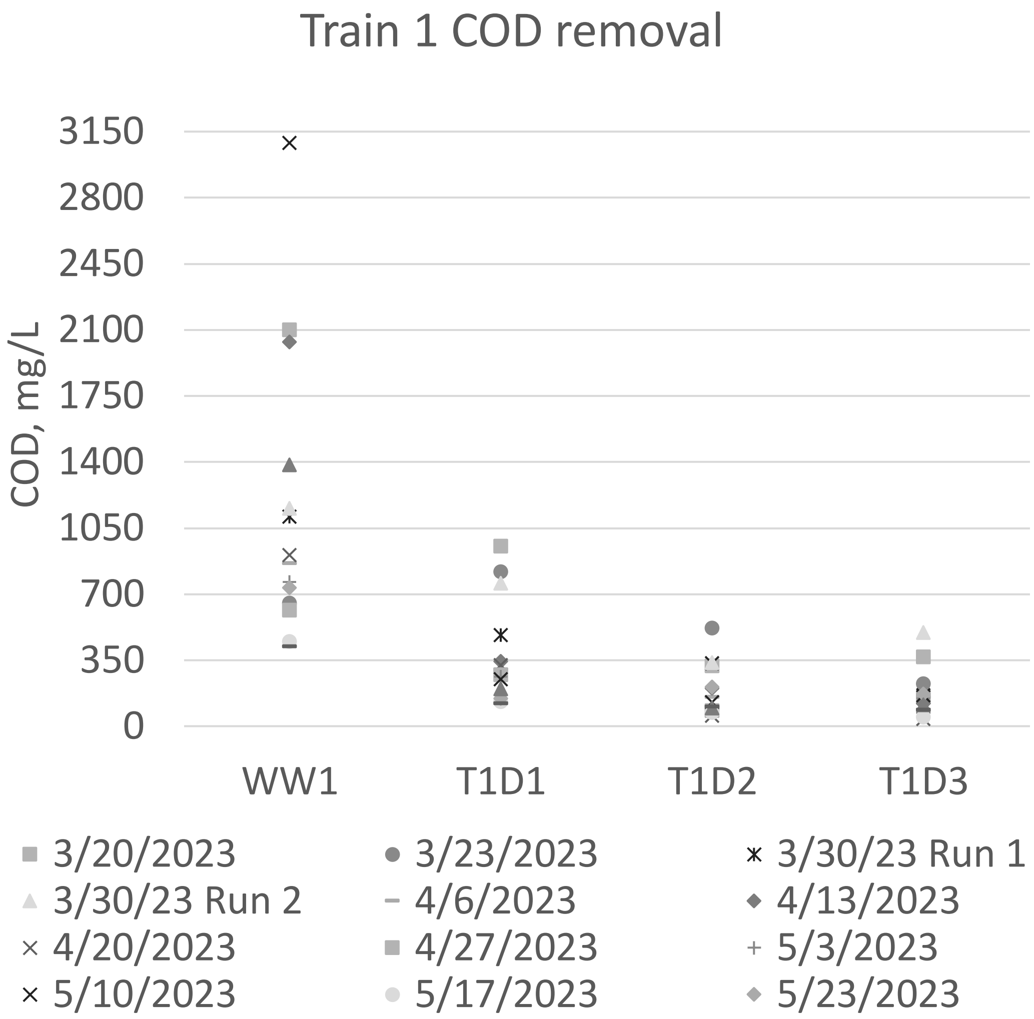
Wastewater recipes

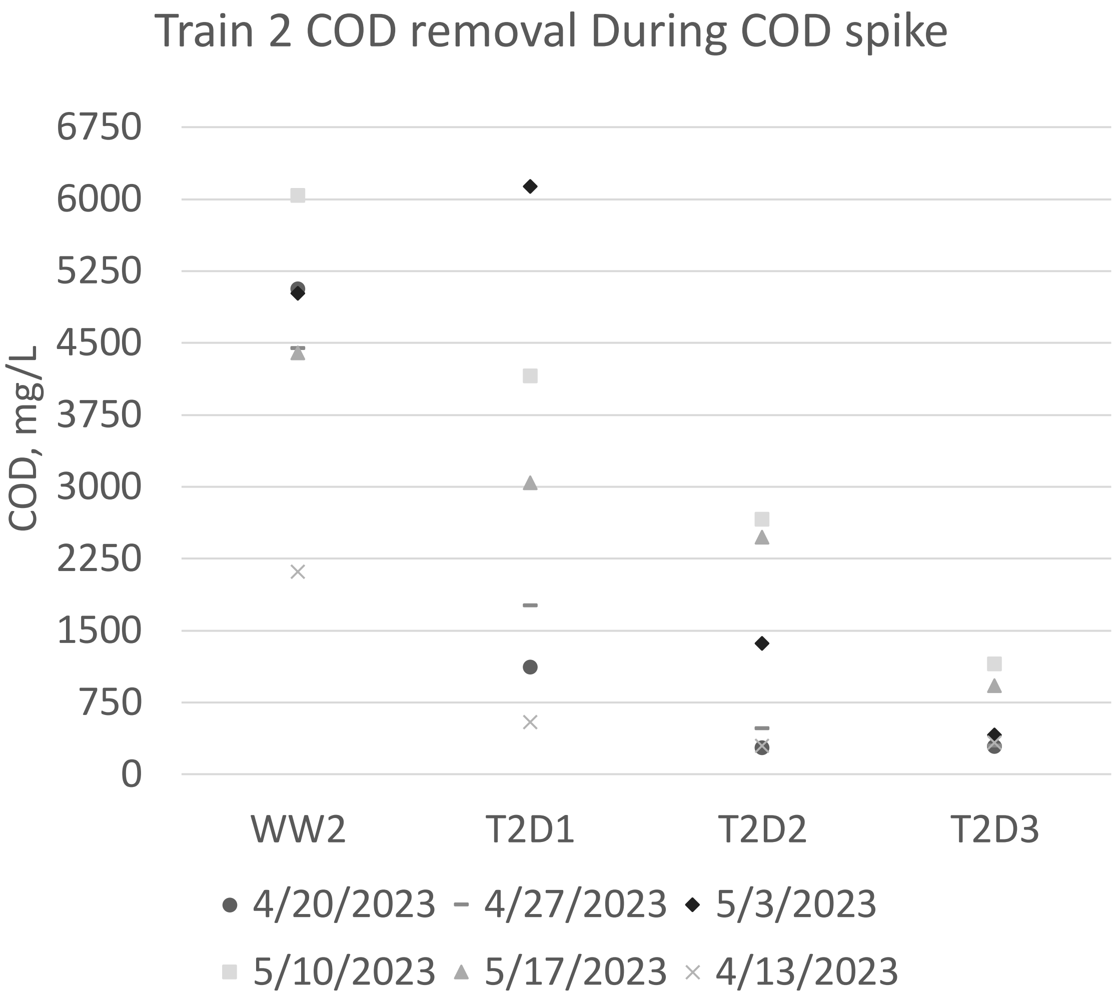
All recipes are for 6 gallons. Diluted juice is in a 1:20 ratio.

- The base synthetic wastewater: 46 mL ethanol, 75.0 mL diluted juice, 170 mg sodium phosphate, 1032 mg nitrogen fertilizer, and rest water.
- COD spiked wastewater: 75.0 mL ethanol, 570 mL dilute juice, 170 mg sodium phosphate, 1032 mg nitrogen fertilizer, and rest water.
- Nutrient spiked wastewater: 46 mL ethanol, 75 mL diluted juice, 1040 mg sodium phosphate, 3100 mg nitrogen fertilizer, and the rest water.
- COD and nutrient spiked wastewater: 75 mL ethanol, 570 mL diluted juice, 850 mg fertilizer, 5160 mg fertilizer, and the rest water.
- Nutrient and salt spiked wastewater: 46 mL ethanol, 75 mL diluted juice, 15,567 mg salt, 1040 mg sodium phosphate, 3100 mg fertilizer, and rest water.

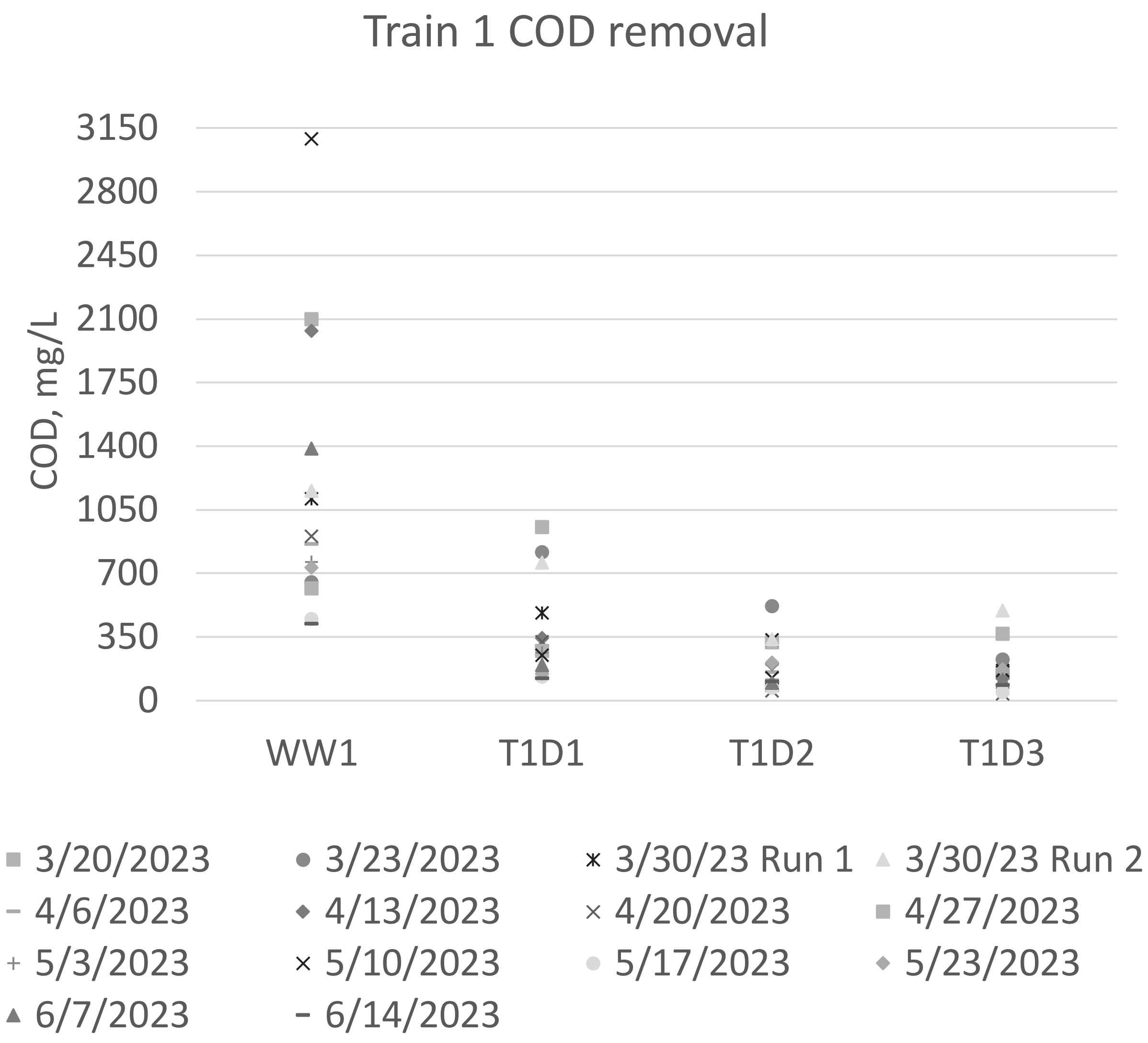

Fridge
T1D1
T2D1
T3D1
T1D2
T2D2
T3D2
T1D3
T2D3
T3D3

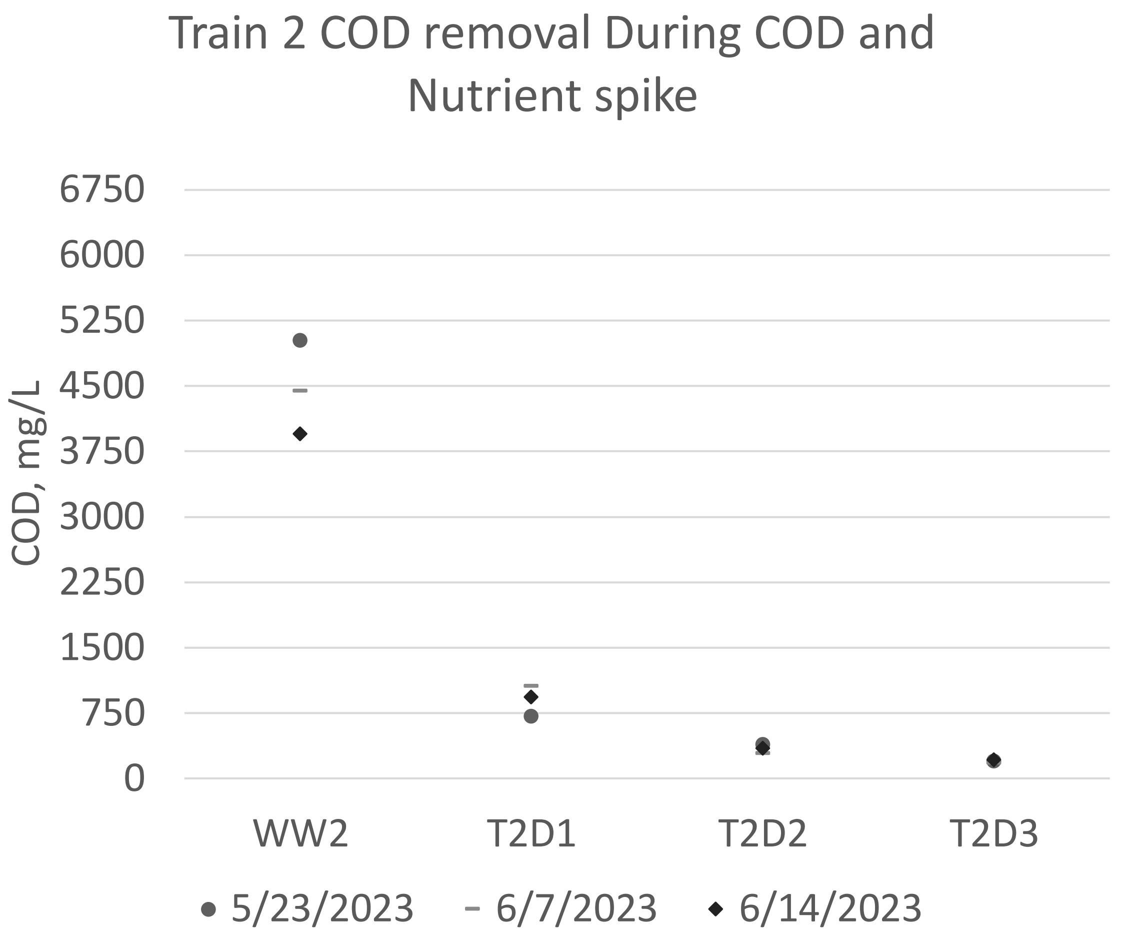
COD removal


Train 1 COD removal
3150
2800
2450
2100
1750
1400
1050
700
350
0
COD, mg/L
WW1
T1D1
T1D2
T1D3
3/20/2023
3/23/2023
3/30/23 Run 1
3/30/23 Run 2
4/6/2023
4/13/2023
4/20/2023
4/27/2023
5/3/2023
5/10/2023
5/17/2023
5/23/2023

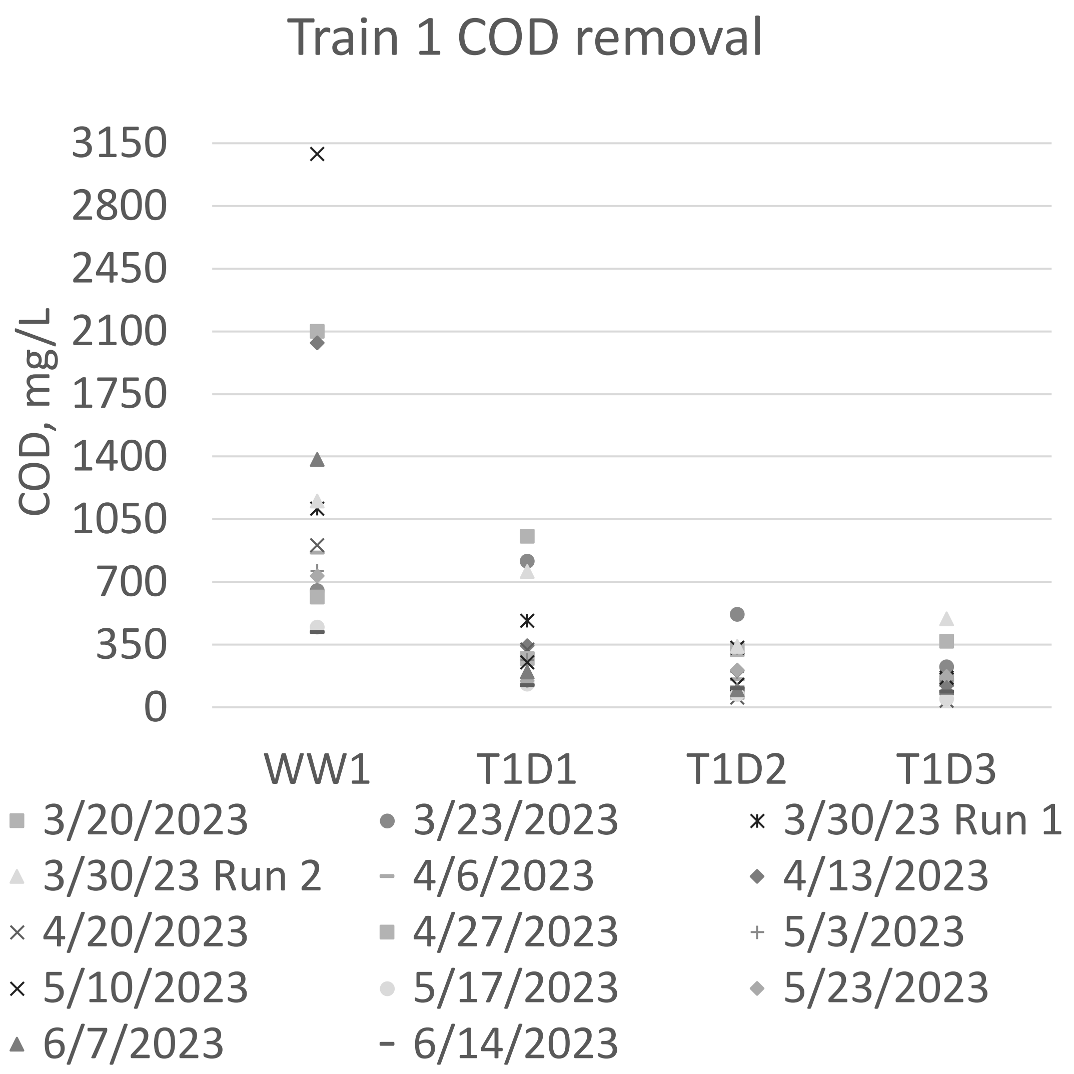

Train 2 COD removal During COD spike
6750
6000
5250
4500
3750
3000
2250
1500
750
0
COD, mg/L
WW2
T2D1
T2D2
T2D3
4/20/2023
4/27/2023
5/3/2023
5/10/2023
5/17/2023
4/13/2023

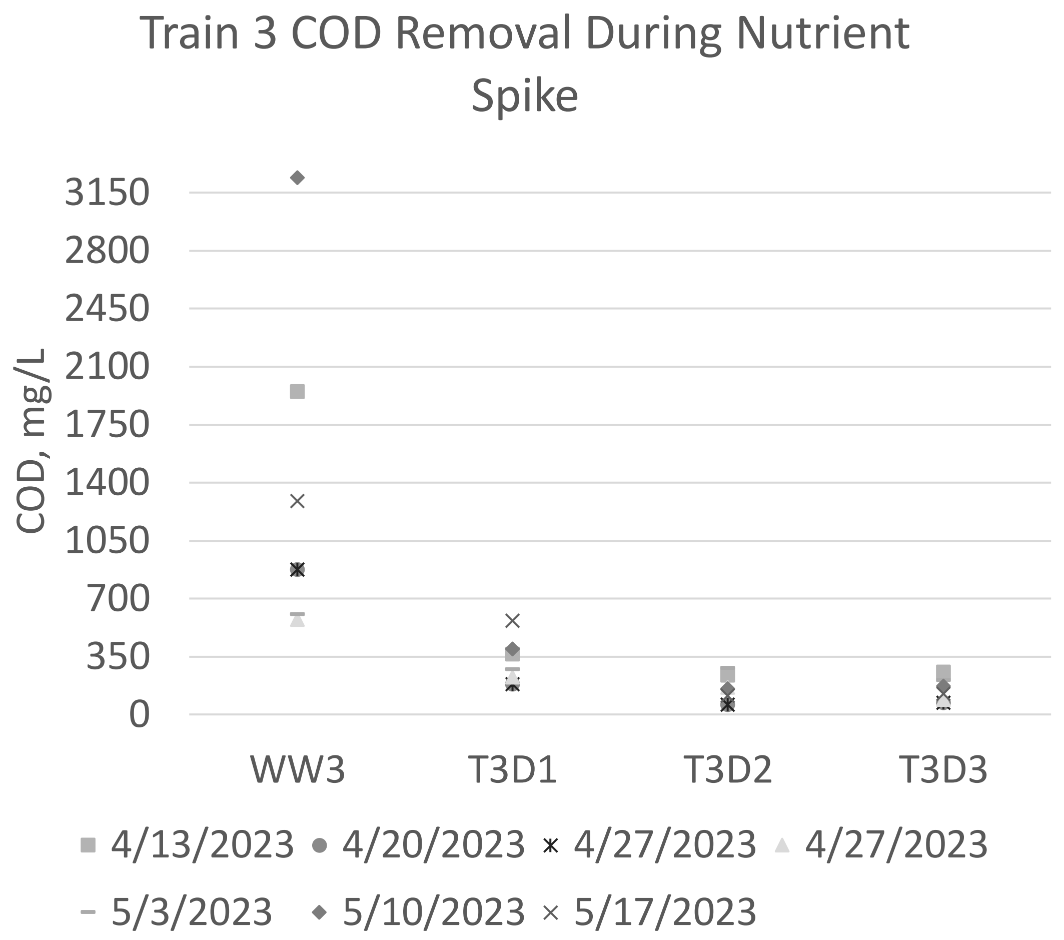
COD Removal Continued



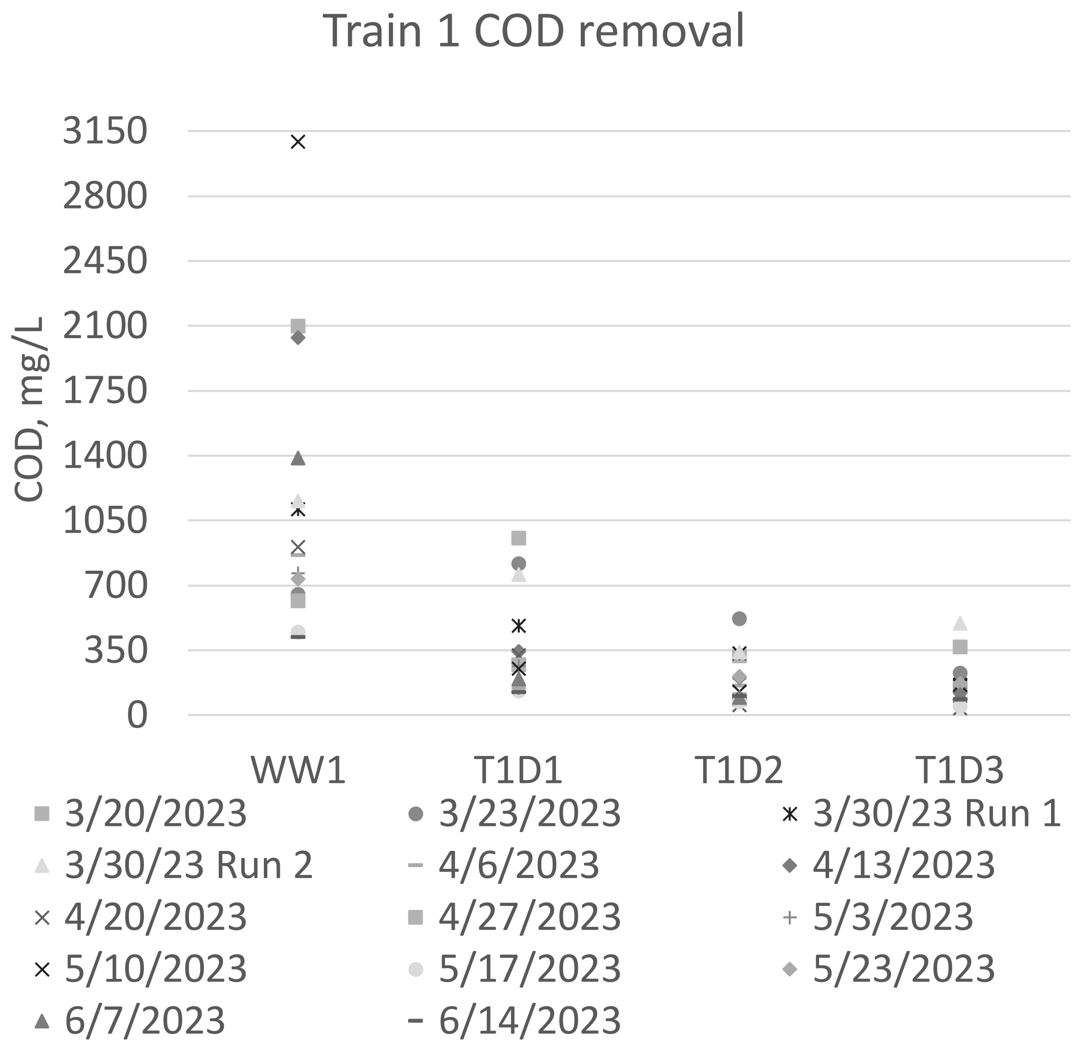


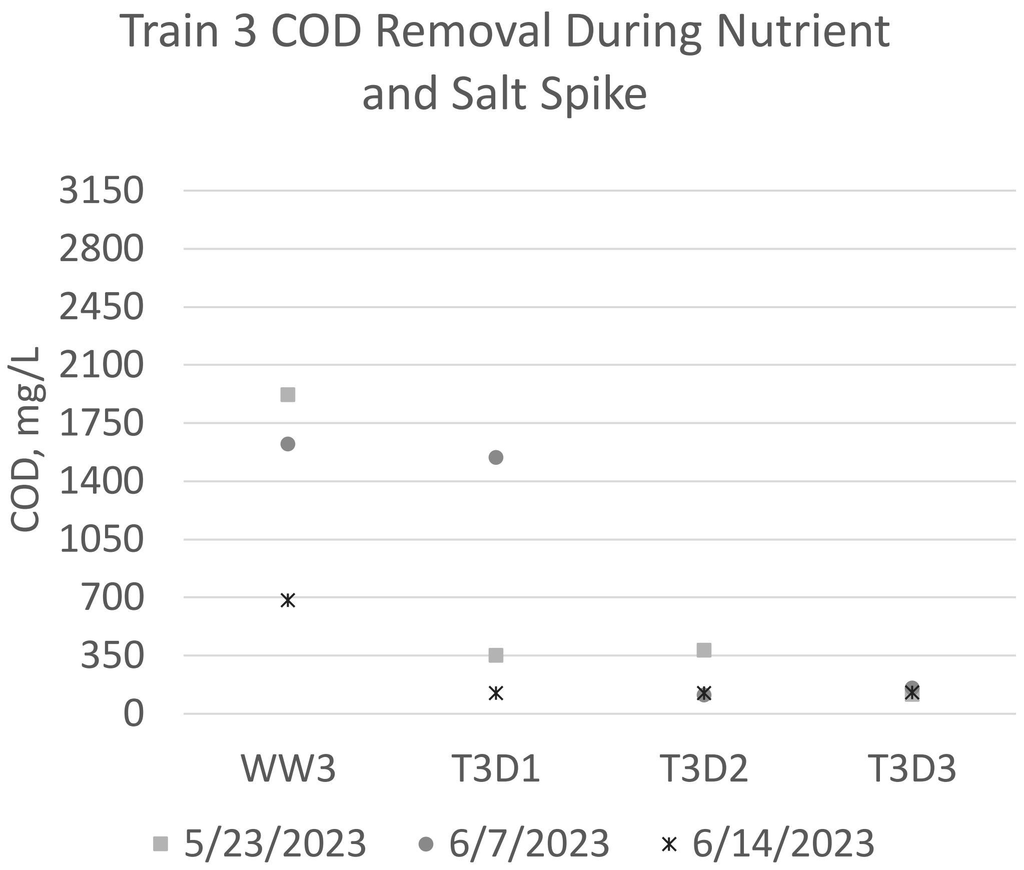
COD Removal Continued



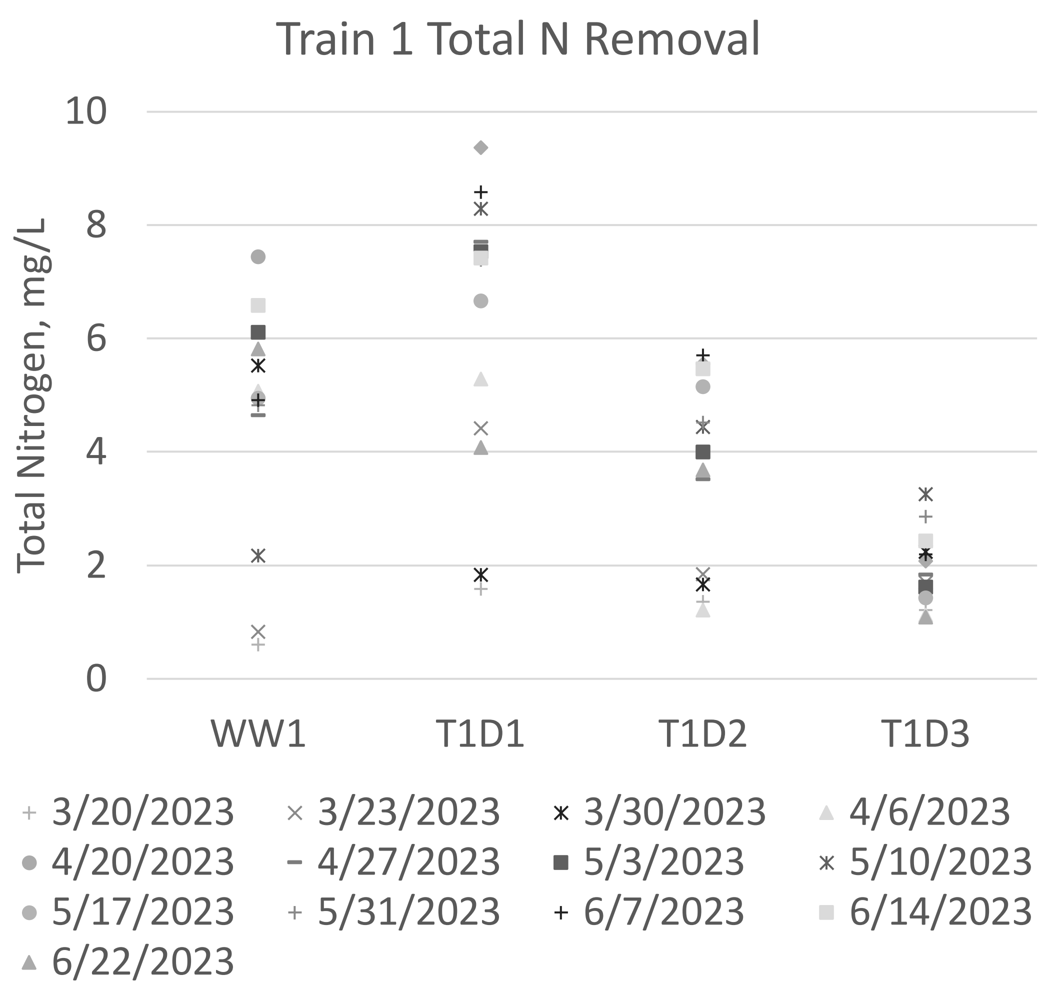


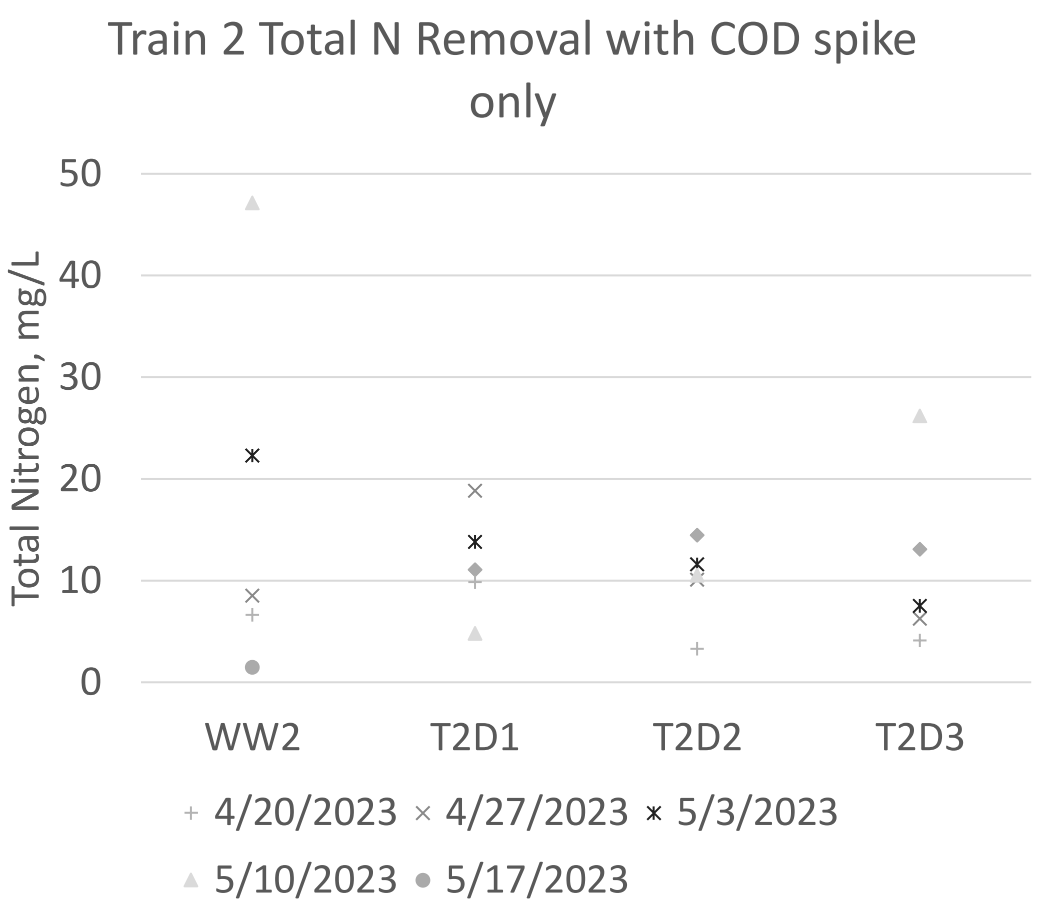
COD Removal Continued





Total Nitrogen Removal





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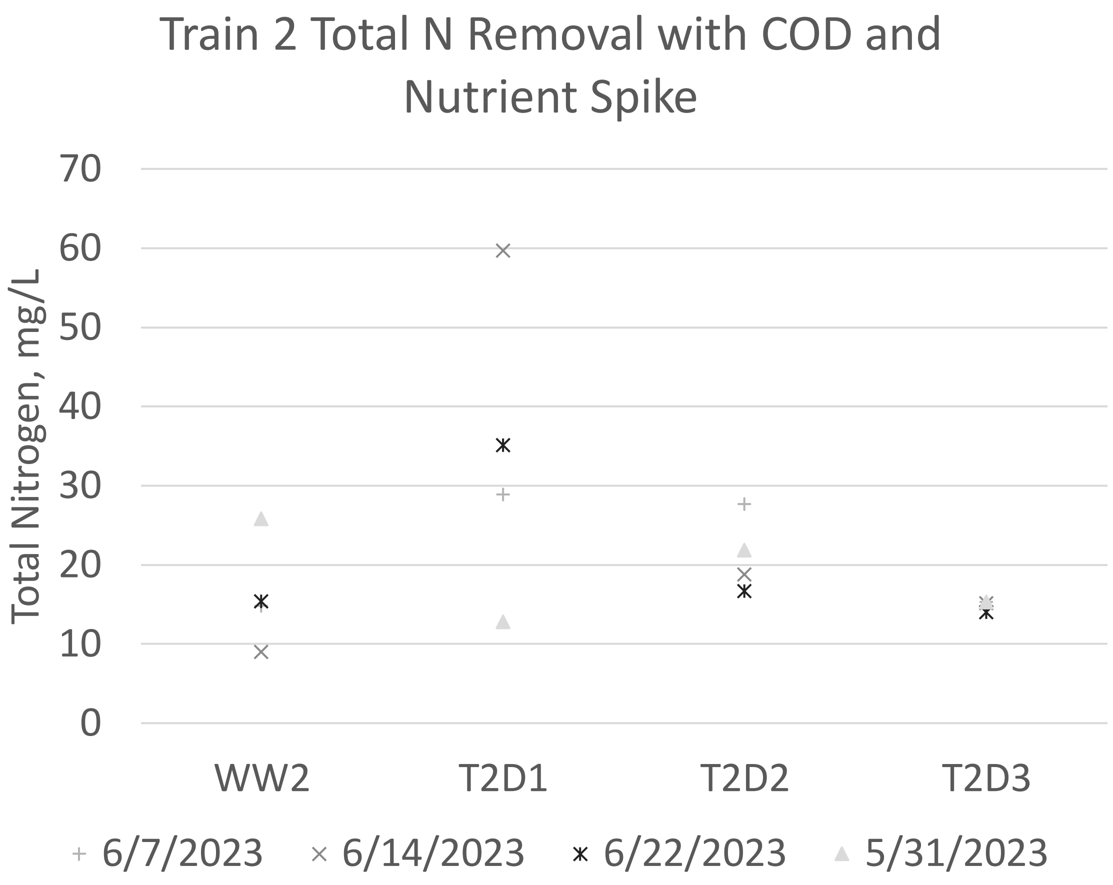

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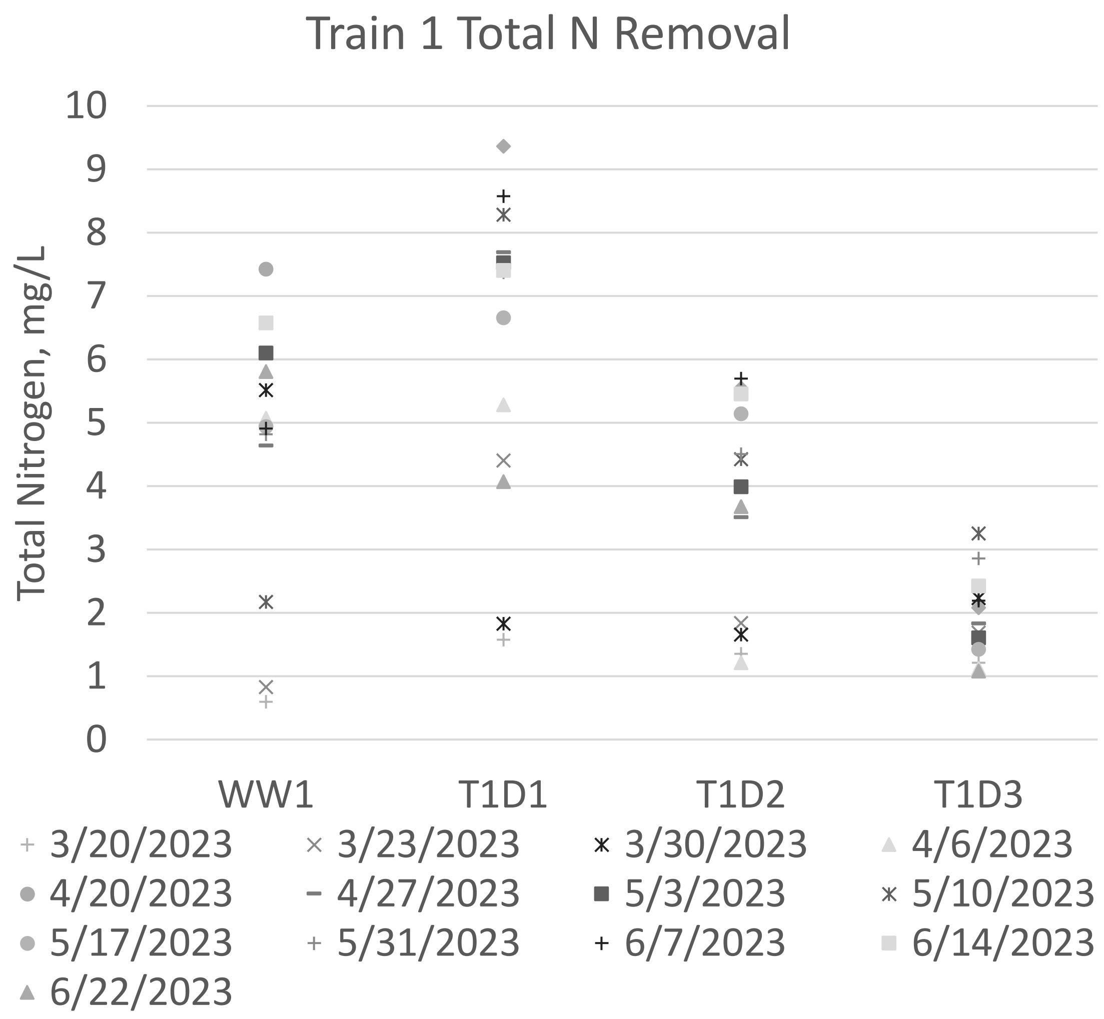
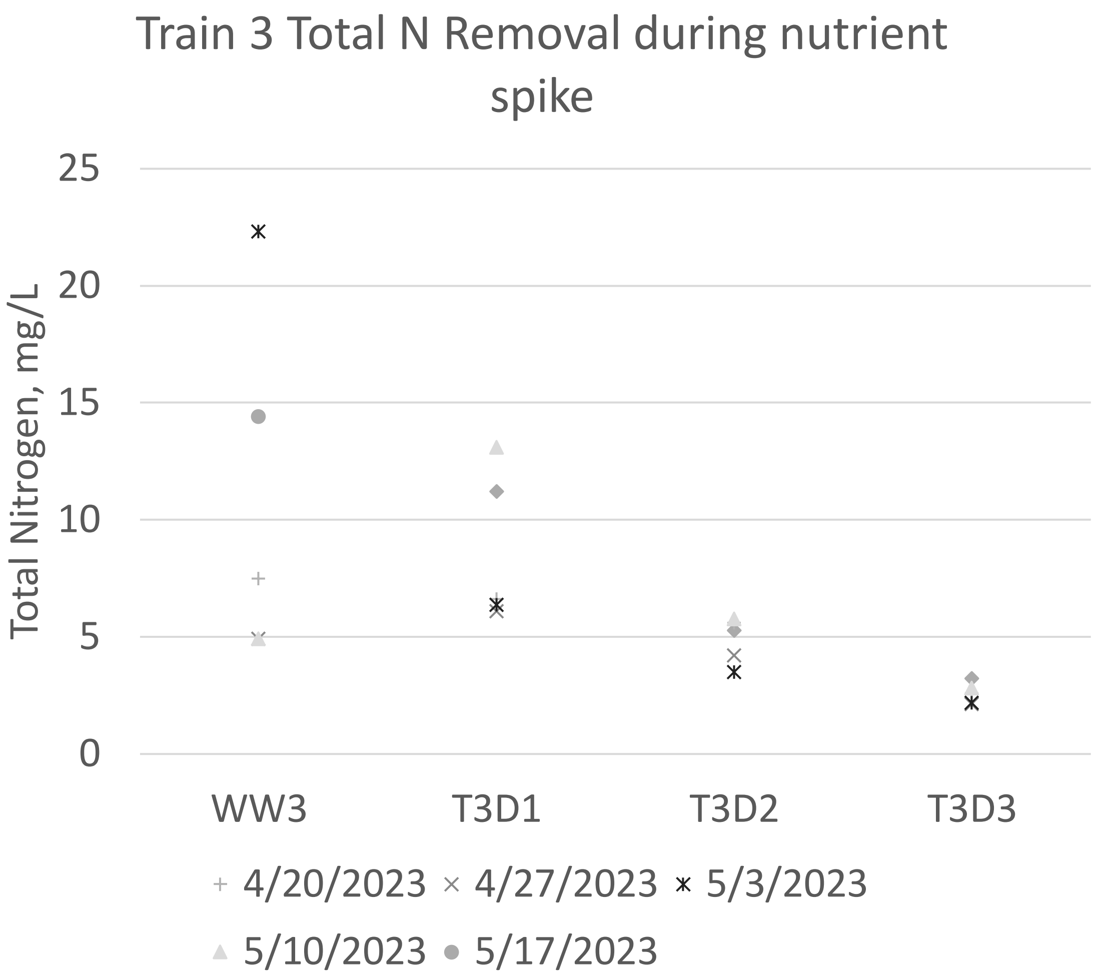
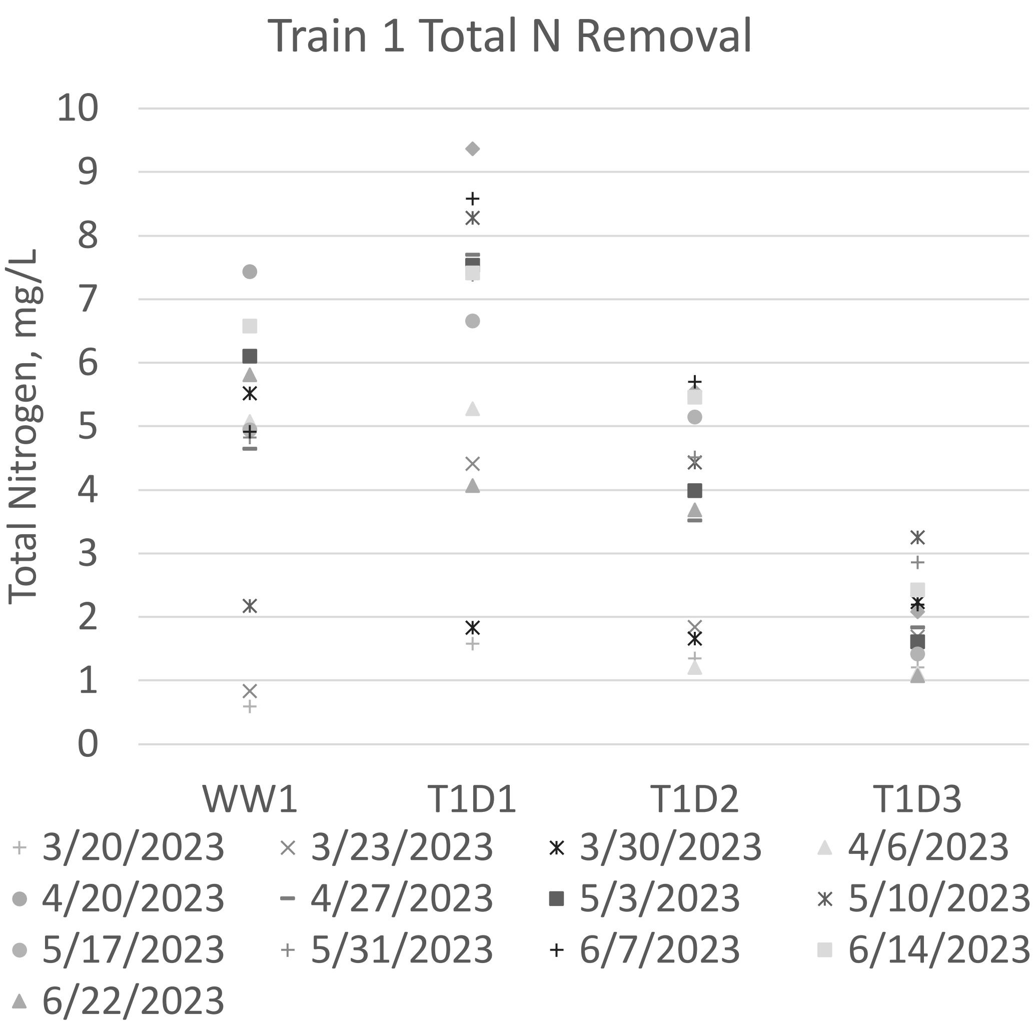
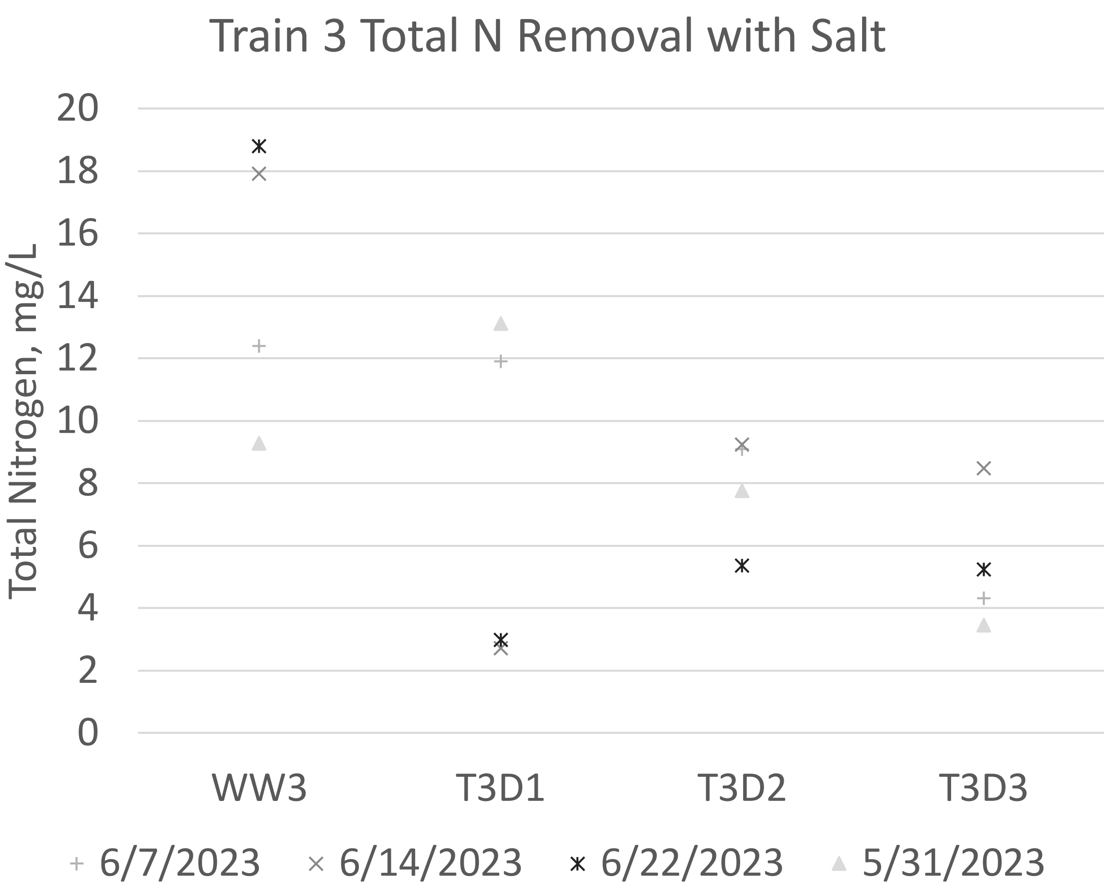


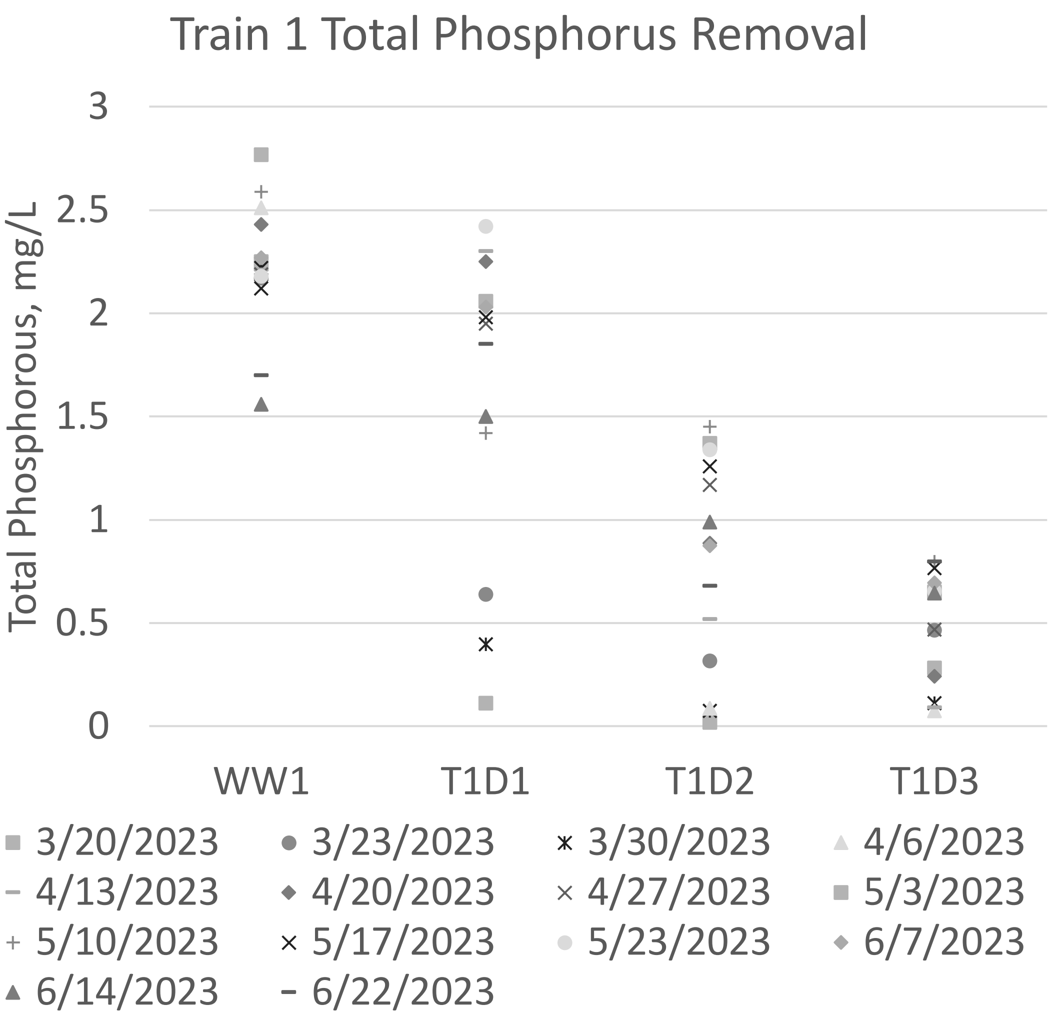


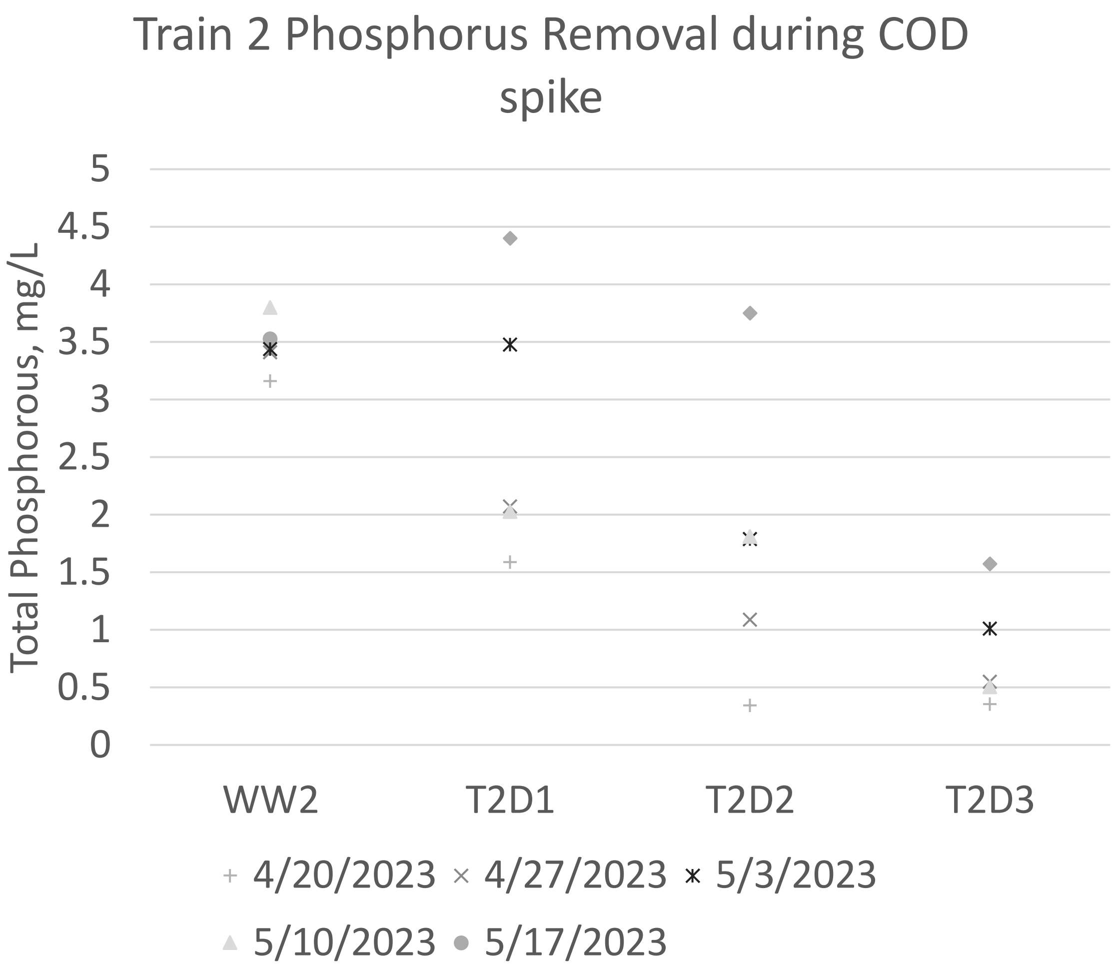
Total Nitrogen Removal Continued





Total Phosphorus Removal





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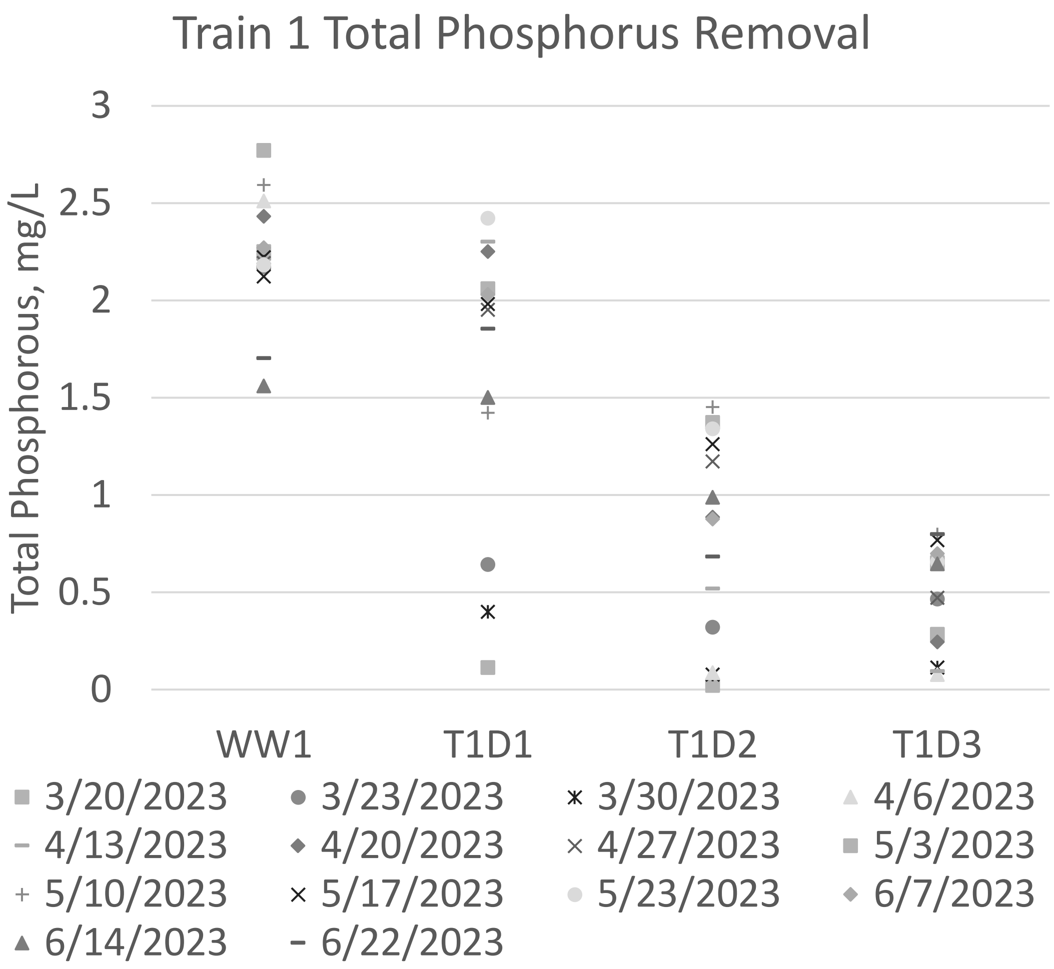

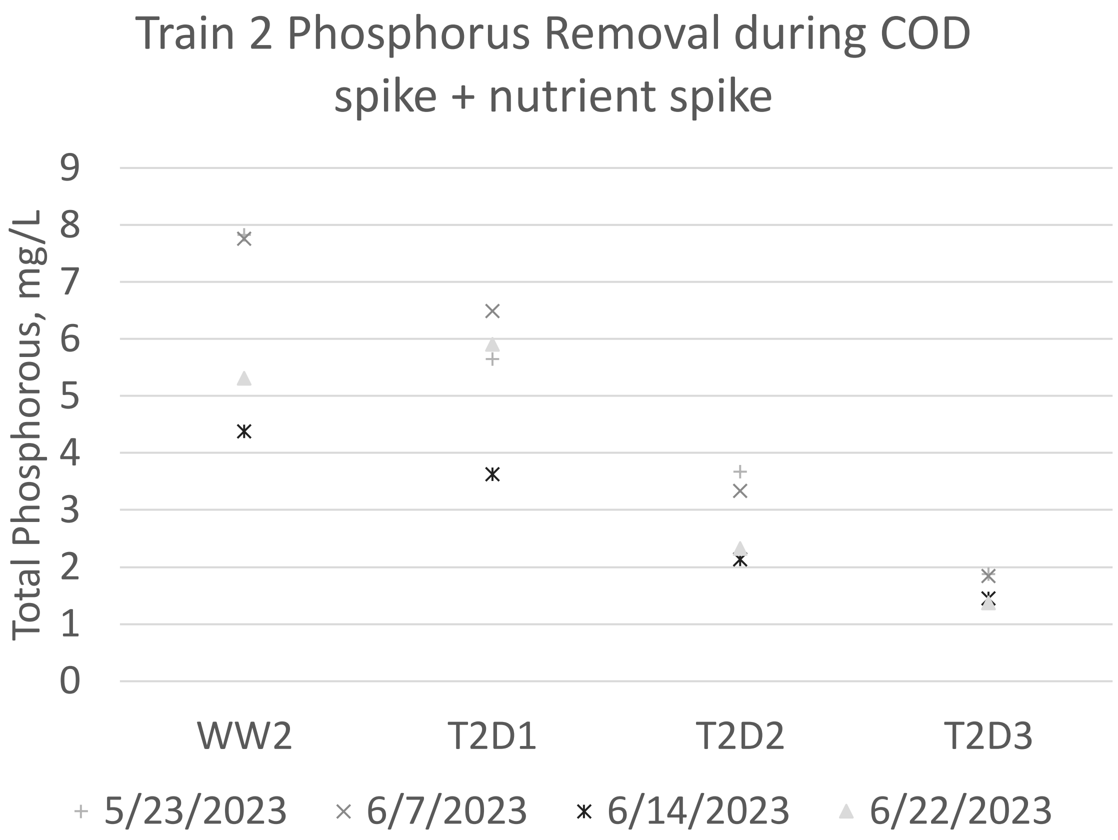

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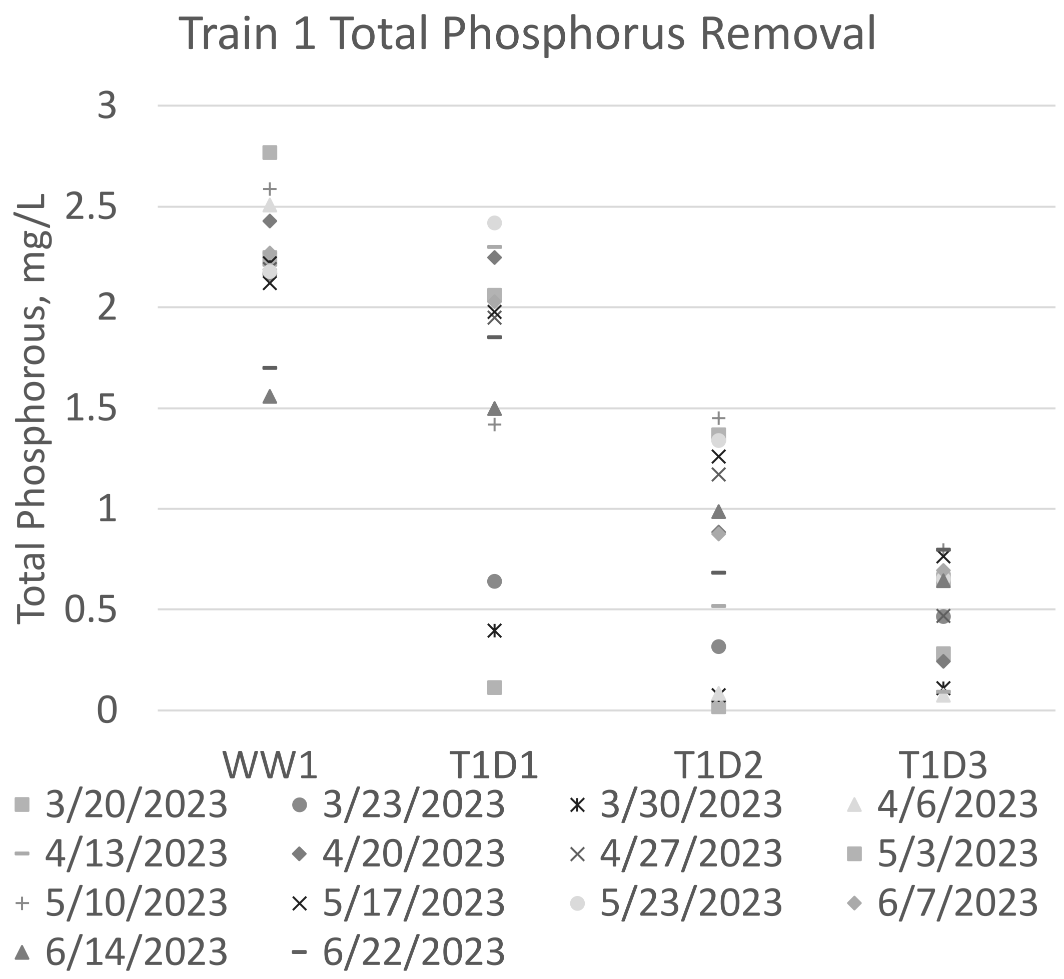
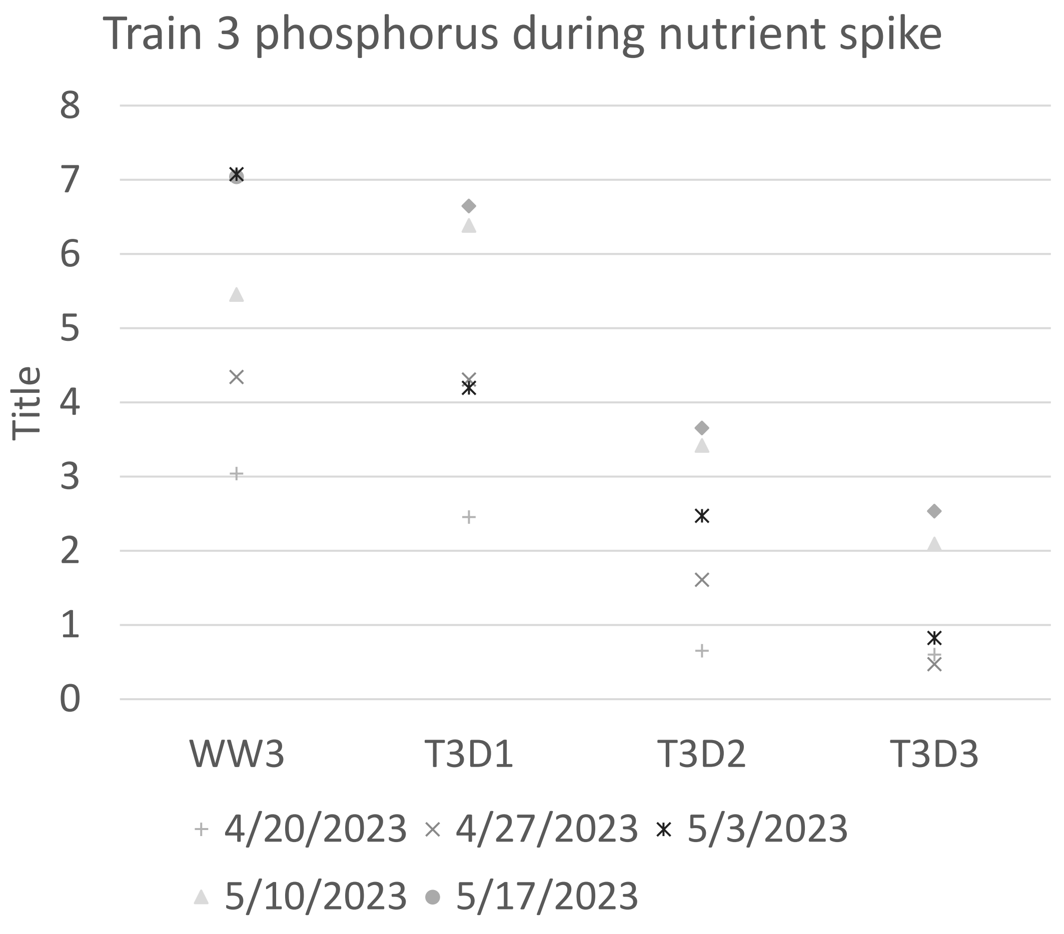
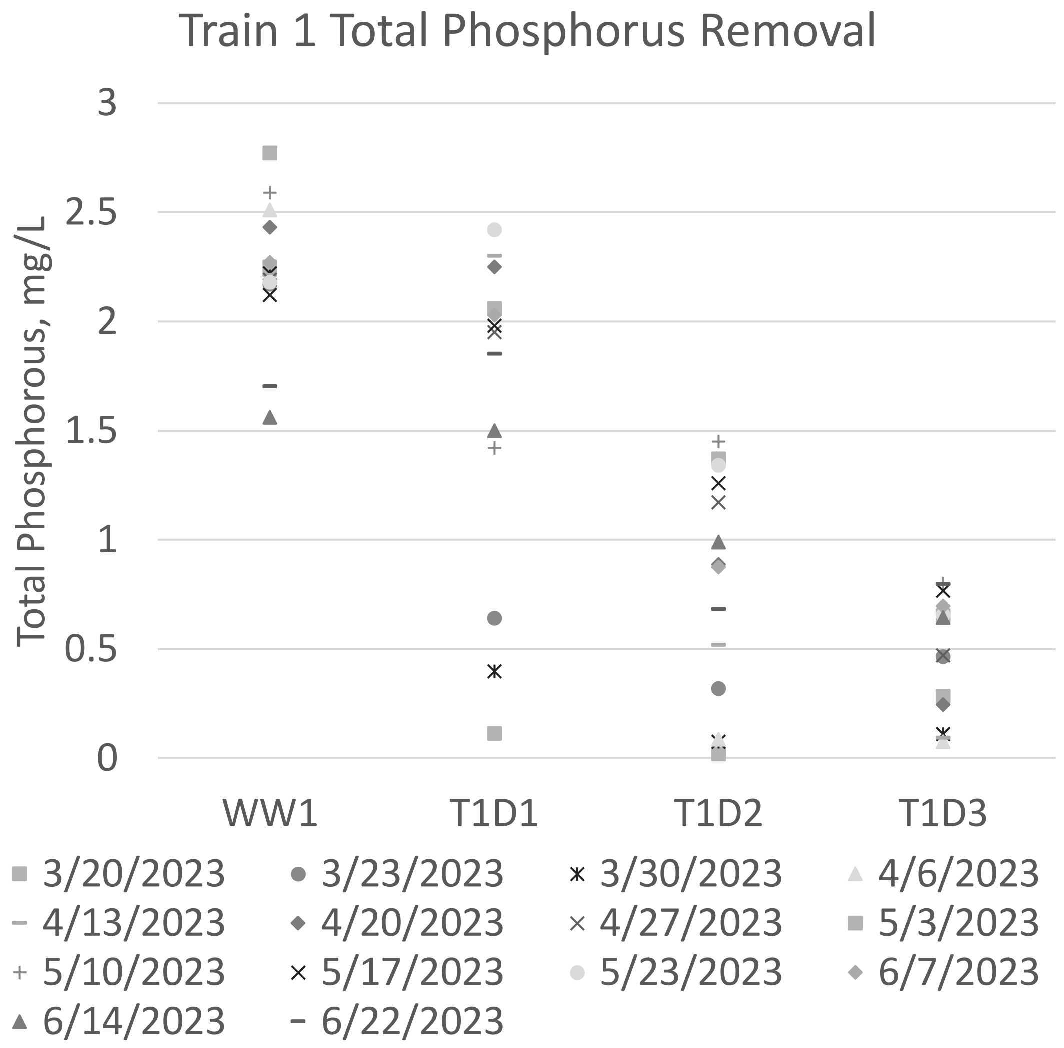
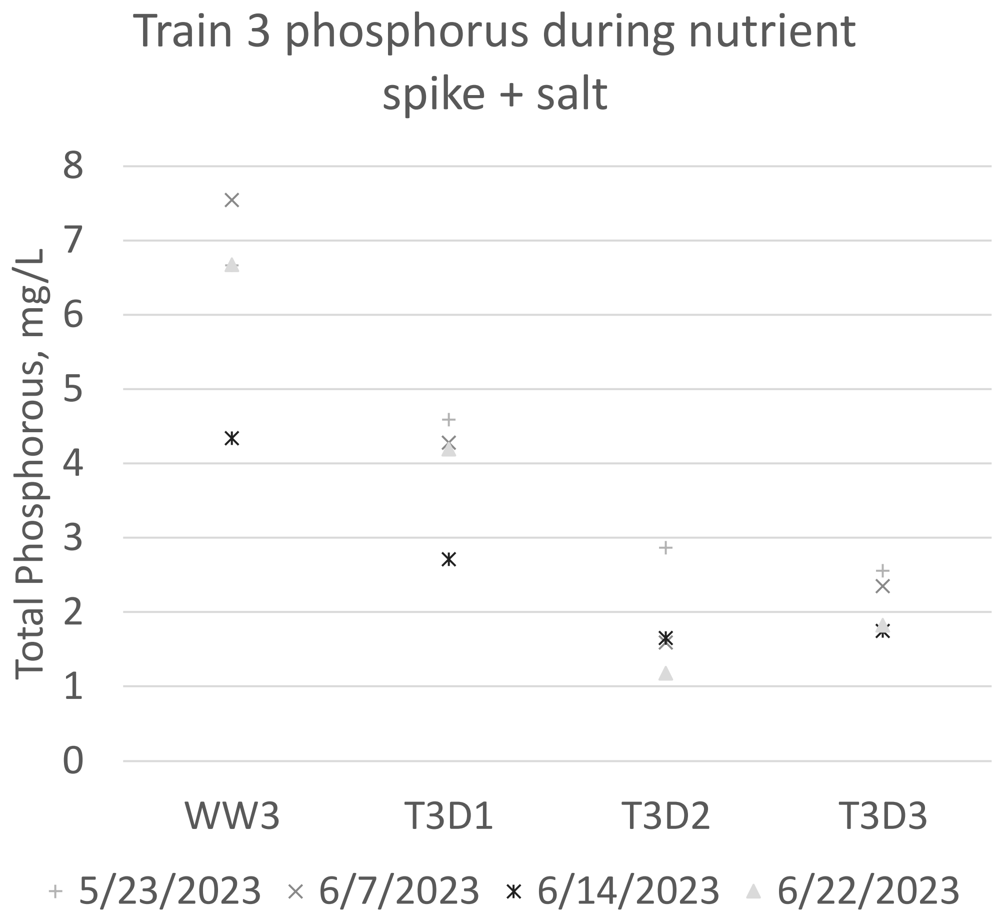




Total Phosphorus Removal Continued





Conclusions and Next Steps

- Greenhouse ecosystem effectively treated synthetic wastewater at the design organic and hydraulic loadings.
- COD spikes caused system failure.
- Similar treatment patterns were found with actual winery, cidery, and brewery wastewaters.
- Attraction!
- Field scale demonstrations

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Contact

Carley Allison

alliso68@msu.edu

Steve Safferman

steves@msu.edu