Efficacy of a Calcium Additive in Sodified Vertisol Soil from the Alabama Black Belt

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WATERS
WATER AND THE ENVIRONMENT'S RESILIENCY AND SUSTAINABILITY

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Alabama Black Belt

- Named after Blackland Prairie Soil Group
  - Marine deposits
  - Rich in organic matter
- Cotton plantations
- Poor and neglected today



Black Belt Soil

- Vertisol
- High clay content
- Strong water retention
- Extreme shrink-swell behavior
- High cation exchange capacity (CEC)





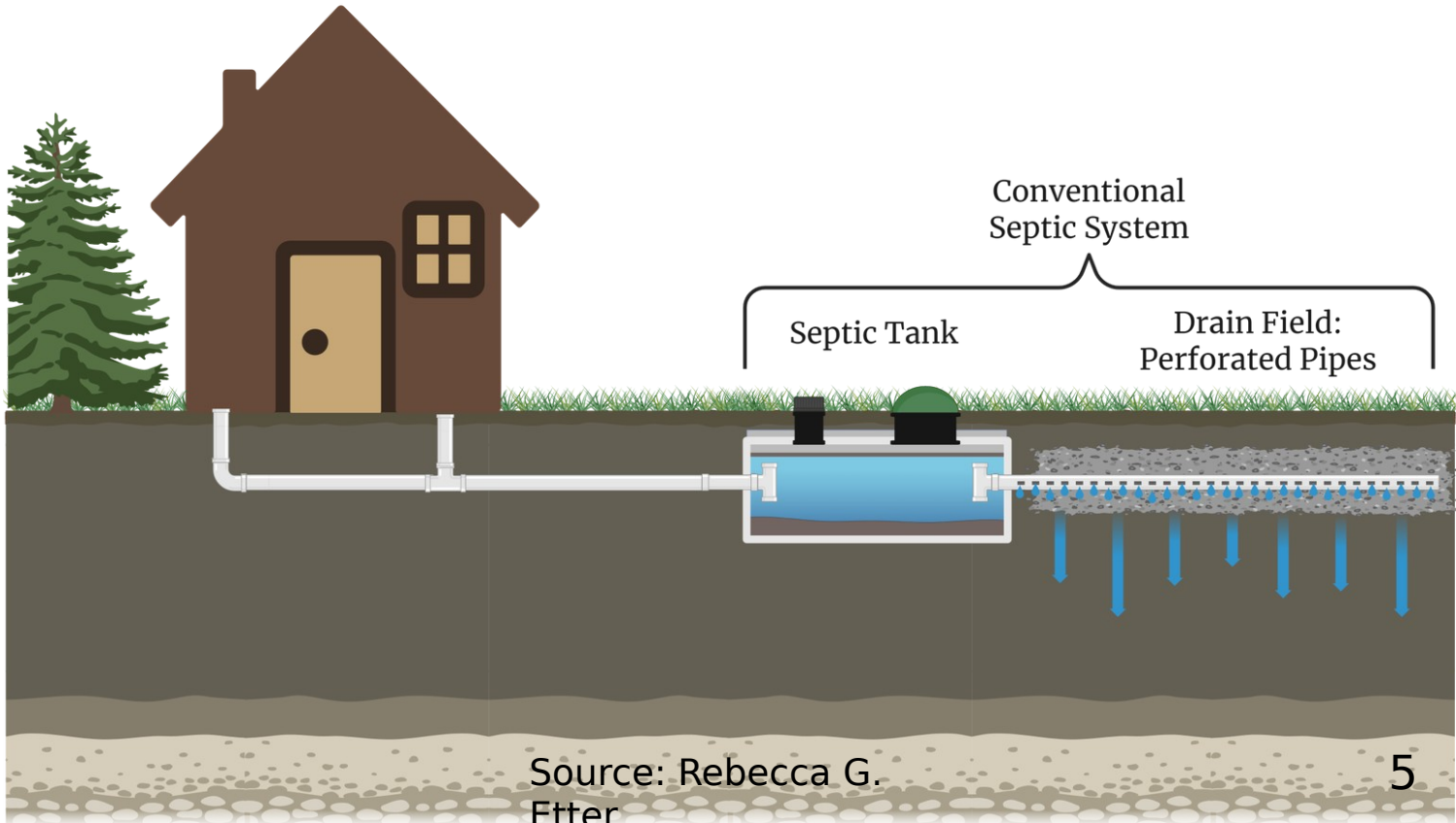


Photo 1. *Soil conditions for onsite wastewater treatment systems in the Alabama Black Belt.*

Source: Maxcy-Brown et al, 2024

Onsite Wastewater Treatment Systems

- 170k in the Black Belt
  - ~26% of Alabama's OWTS
- Drainfield
- Failure
- Straight pipes



Source: Rebecca G. Etter

Ion Issue

- OWTS fail to remove dissolved ions
- Effluent contains an estimated 120-160 mg/L Na^+
  - Common in waste streams
- Affect soil structure
  - Sodification
  - Salinization

Sodification & Salinization

Sodification

- Caused by +1 ions
  - Na^{+} & K^{+}
- Disperses soil particles
- Reduces hydraulic performance

Salinization

- Caused by +2 ions
  - Ca^{2+} & Mg^{2+}
- Flocculates soil particles
- Can poison environment

Soil Physics

- Isomorphic Substitution
  - Negative charge
- Diffuse Double Layer
- Ions bridge soil particles
- Replacement

Source: Mitchell & Soga

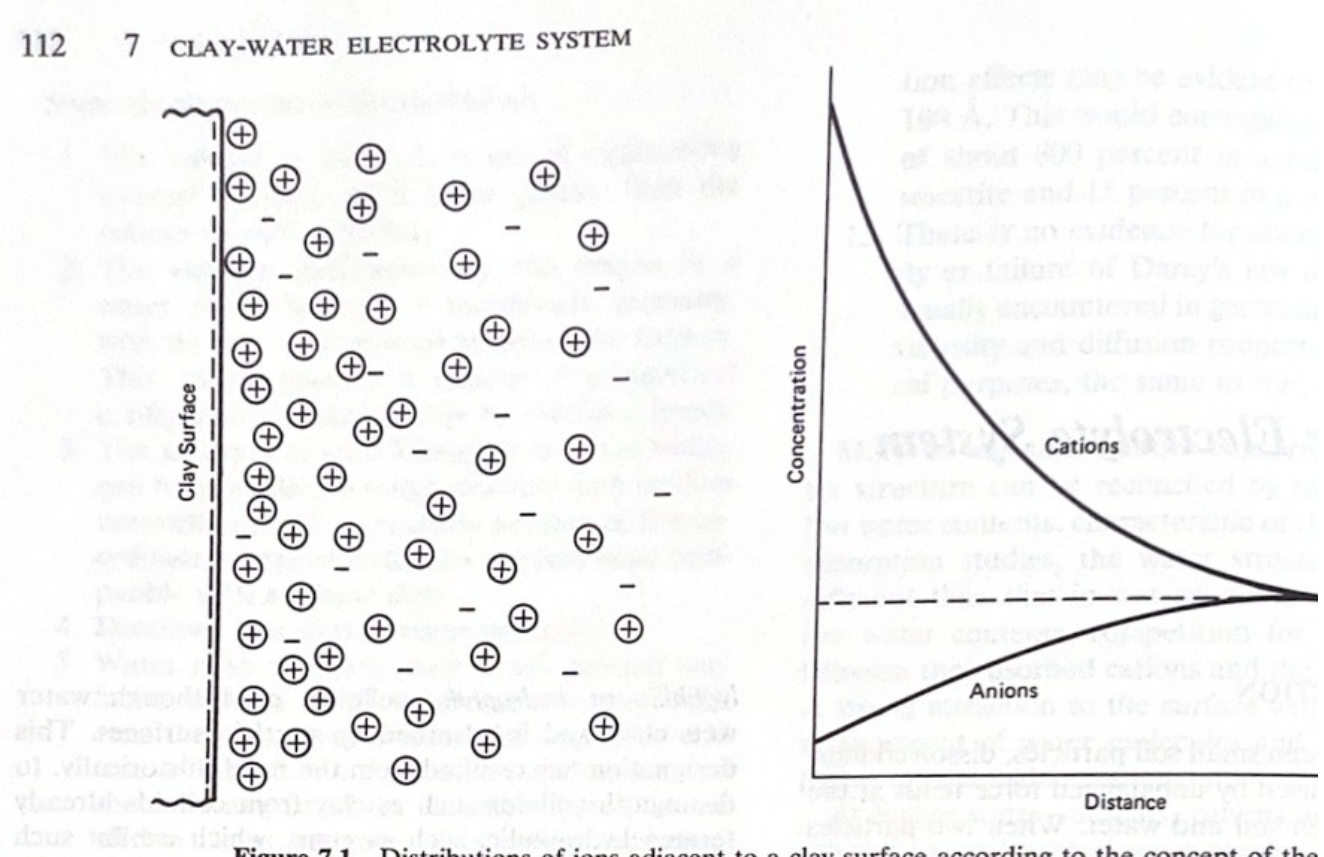
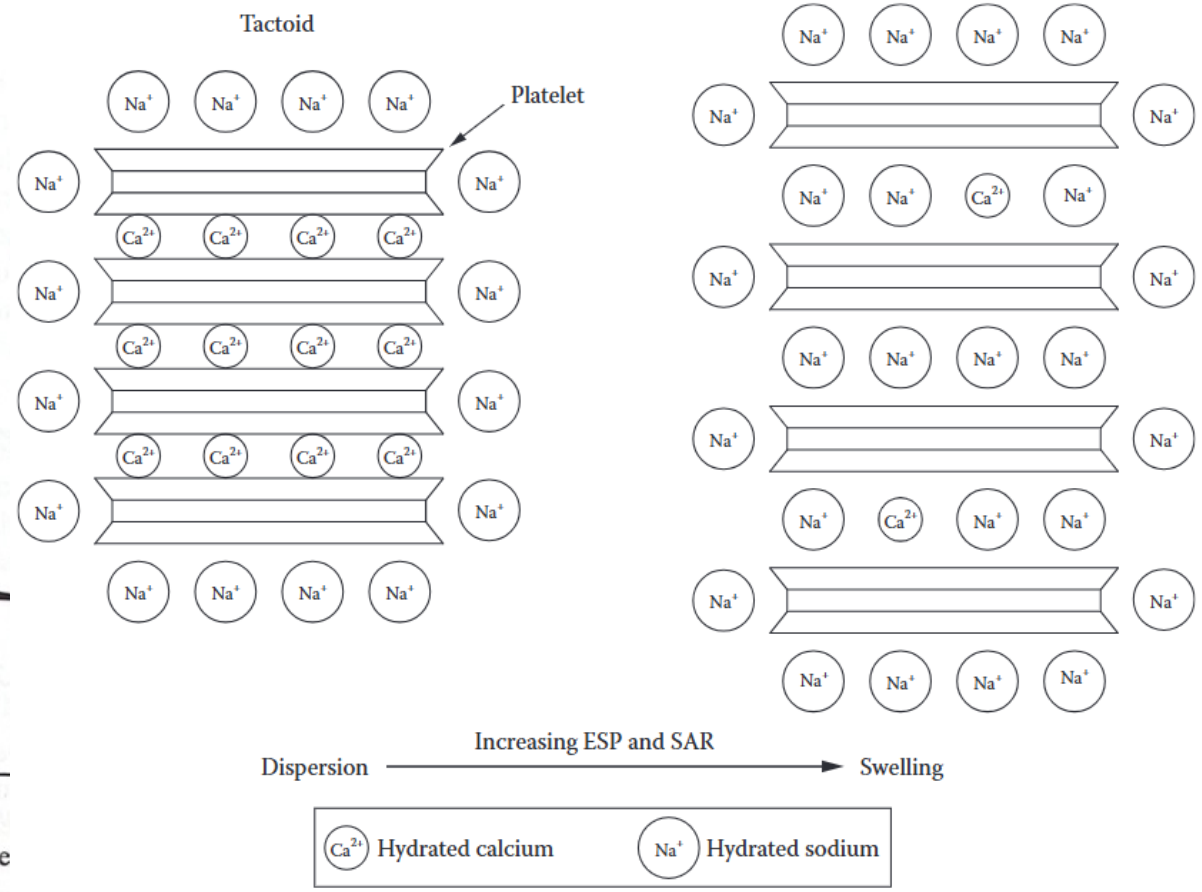


Figure 7.1 Distributions of ions adjacent to a clay surface according to the concept of the diffuse double layer.



Agricultural Practices

- Common Practice in Agriculture
- Gypsum
  - $CaSO_4$
- Fertilizer
- Sodic field remediation



Source: CalciSoil, 2023

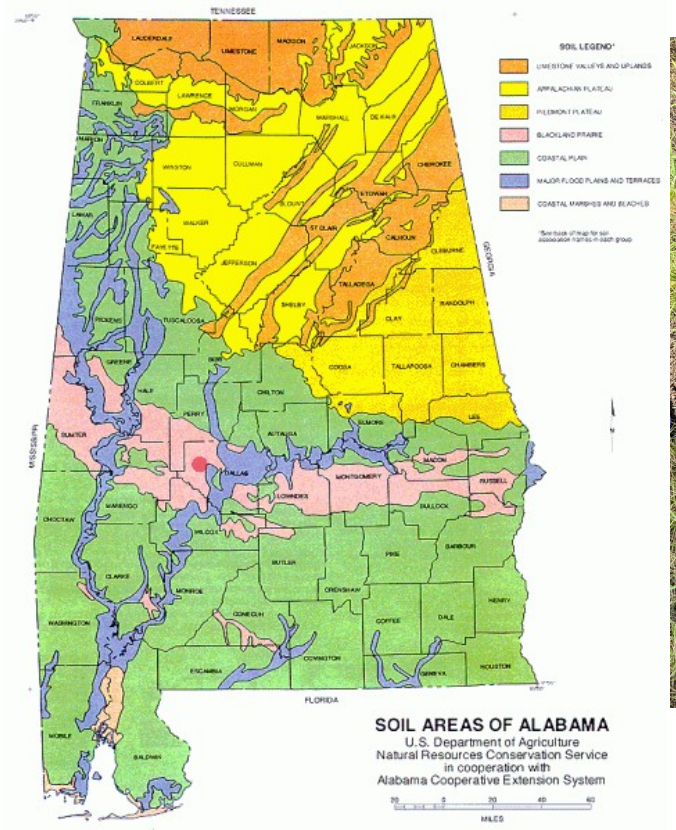
Experimental Design

- Column experiment
- Undisturbed soil samples
- Variety of calcium compounds
- Measure hydraulic properties
  - Infiltration Rate & Hydraulic Conductivity
- Measure Ionic Concentration of effluent



Soil Collection

- Marion Junction Black Belt Research & Extension Center
- Hydration phase
- Extraction phase



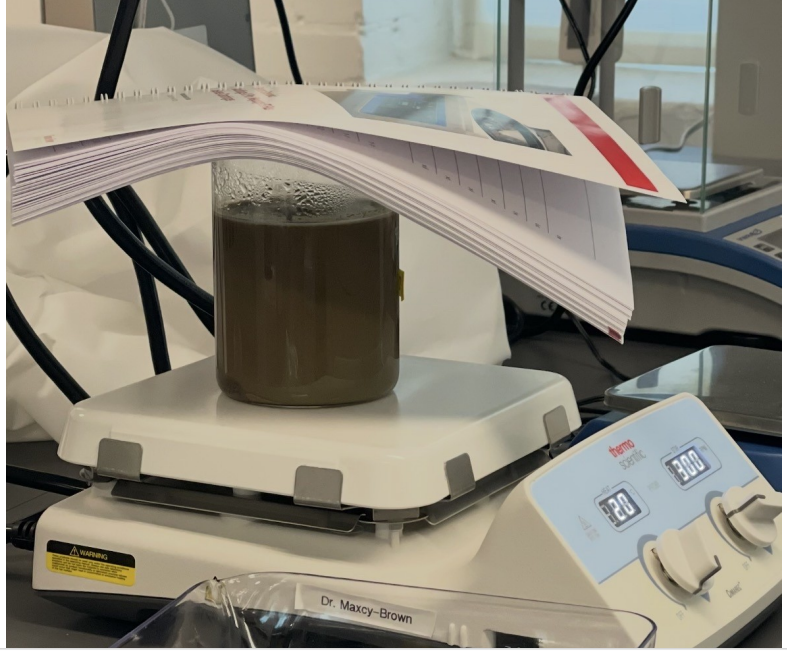
Source: Alabama Cooperative Extension Center

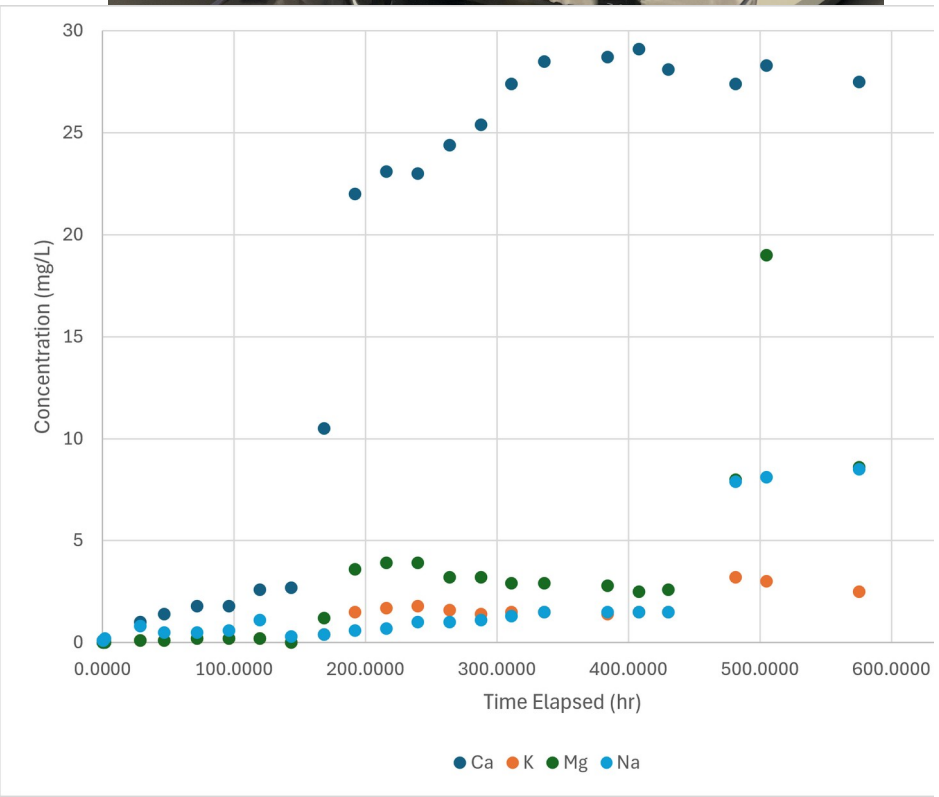




Calcium Selection

- Considerations: accessibility, solubility, cost
- Gypsum – $CaSO_4$
- Calcium Carbonate – $CaCO_3$
  - TUMs
  - Pool calcite
- Calcium Acetate – $Ca(CH_3COO)_2$
- Calcium Nitrate – $Ca(NO_3)_2$



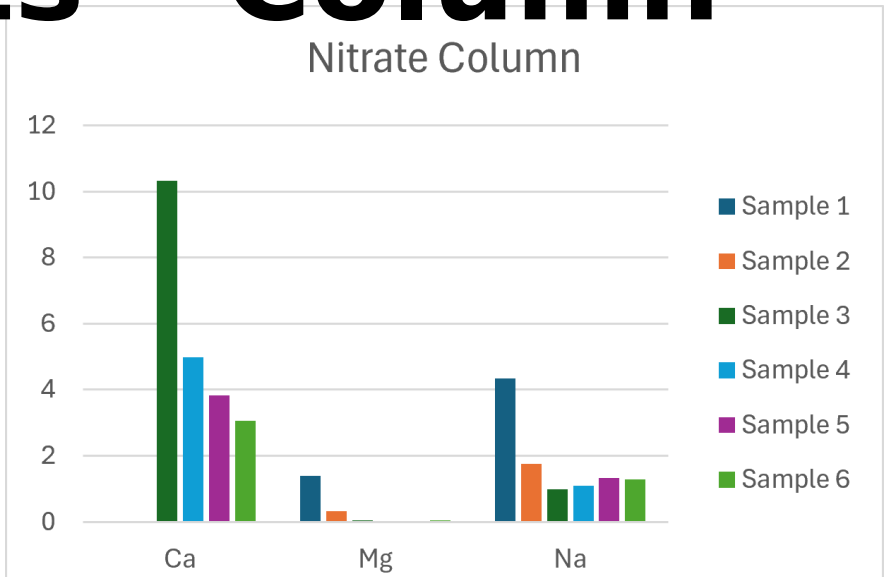


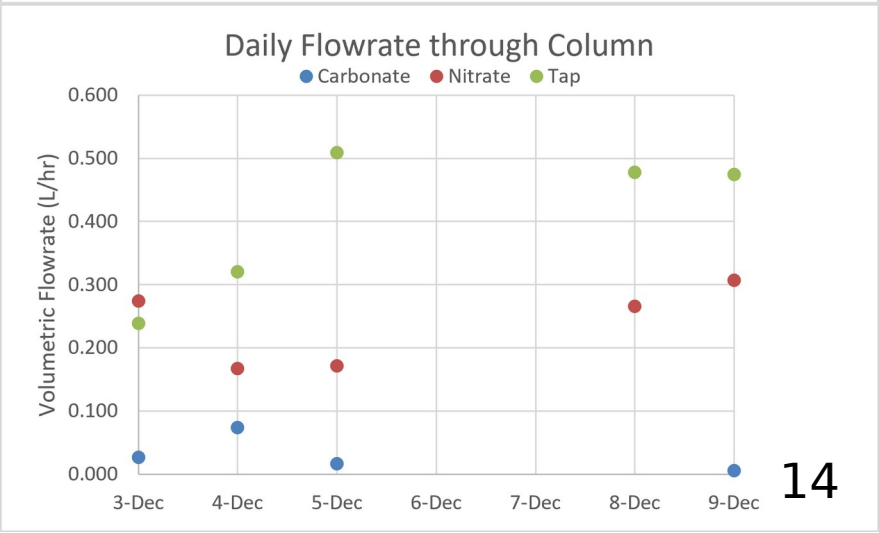
Preliminary Experiments – Leach Test

- Interested in soil content
- Calcium has highest prevalence
- Sodium second
- Aluminium also highly prevalent
- Cannot generalize or use for CEC

Preliminary Experiments – Column Tests

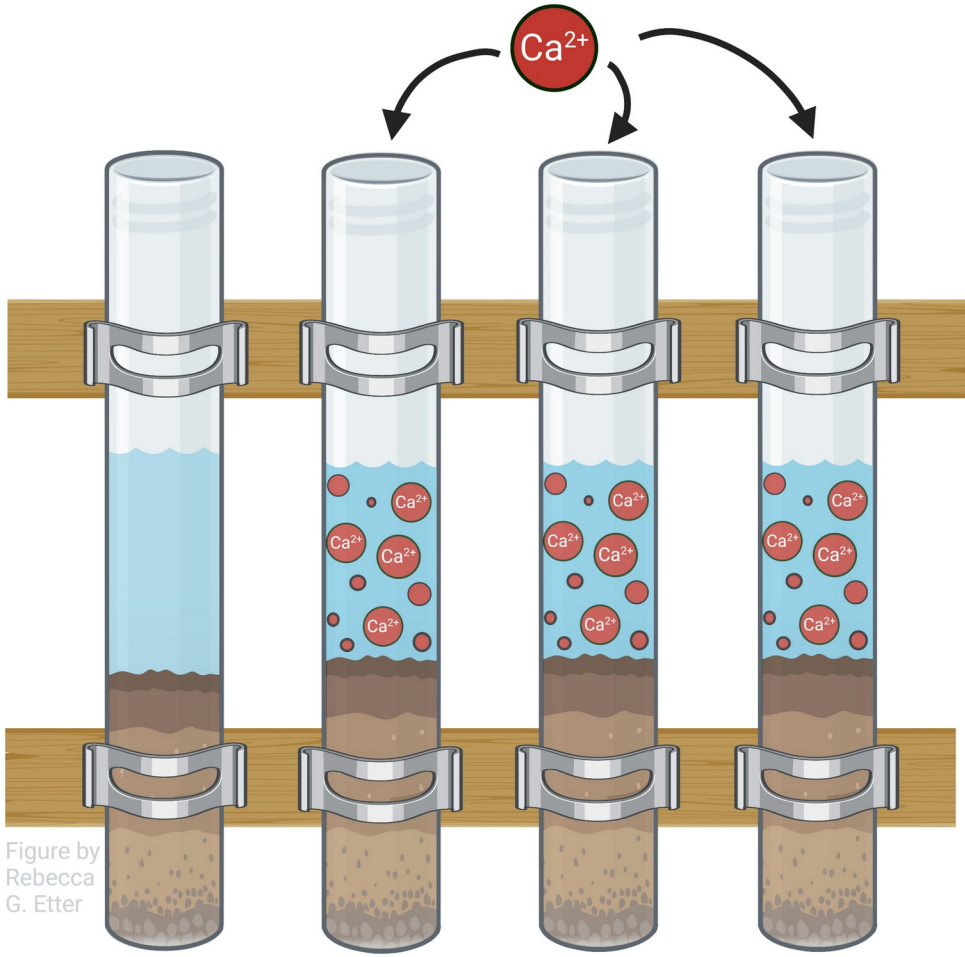
- Three Columns
  - Calcium Carbonate & Calcium Nitrate
  - Tap Control
- 2 L of tap per day
- No sodification
- TUMs failure





Main Experiment - Column Set 1

- Calcium Acetate, Calcium Nitrate, & Tap Colu
- 42 days of testing
- 1 L of 560 mg/L Na^+ per day
  - 1436 mg of NaCl
- 4 days worth of sodium per day
  - Total of 168 days of sodium loading
- 3 days where no testing occurred
  - 6/6, 6/11, 6/12

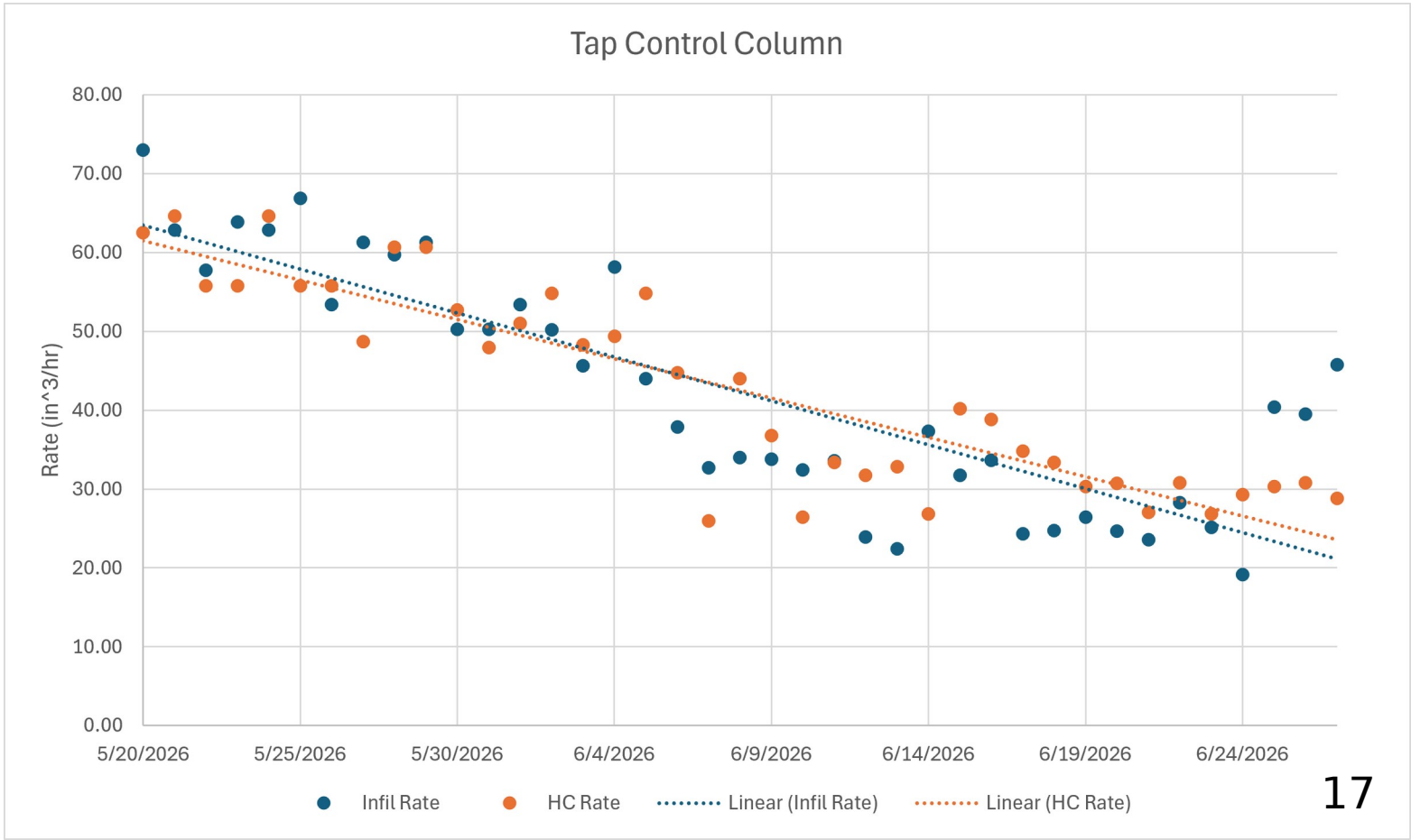


Calcium Remediation

- Calcium remediation on day 35
  - 6/23
- 38 days worth of sodification remediation
  - 11.77 g Ca^{2+}
- 51.070 g of Calcium Acetate
  - 23% Calcium by mass
- 69.216 g of Calcium Nitrate
  - 17% Calcium by mass

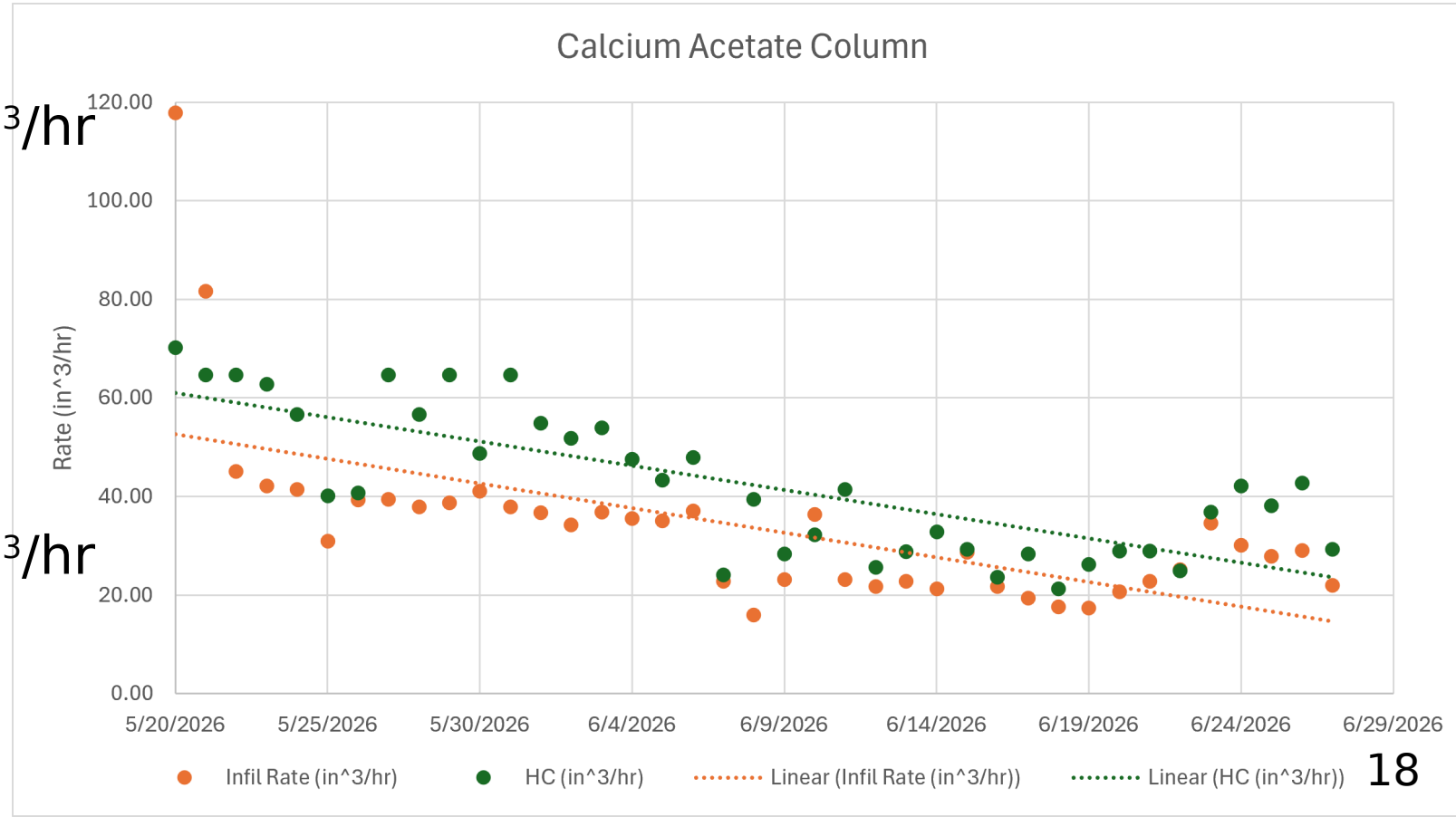
Tap Control Column

- No calcium remediation
- Infiltration Rate
  - Initial: >73 in³/hr
  - 6/23: ~25 in³/hr
  - Final: ~20 in³/hr
- Hydraulic Conductivity
  - Initial: >60 in³/hr
  - 6/23: ~31 in³/hr
  - Final: ~30 in³/hr



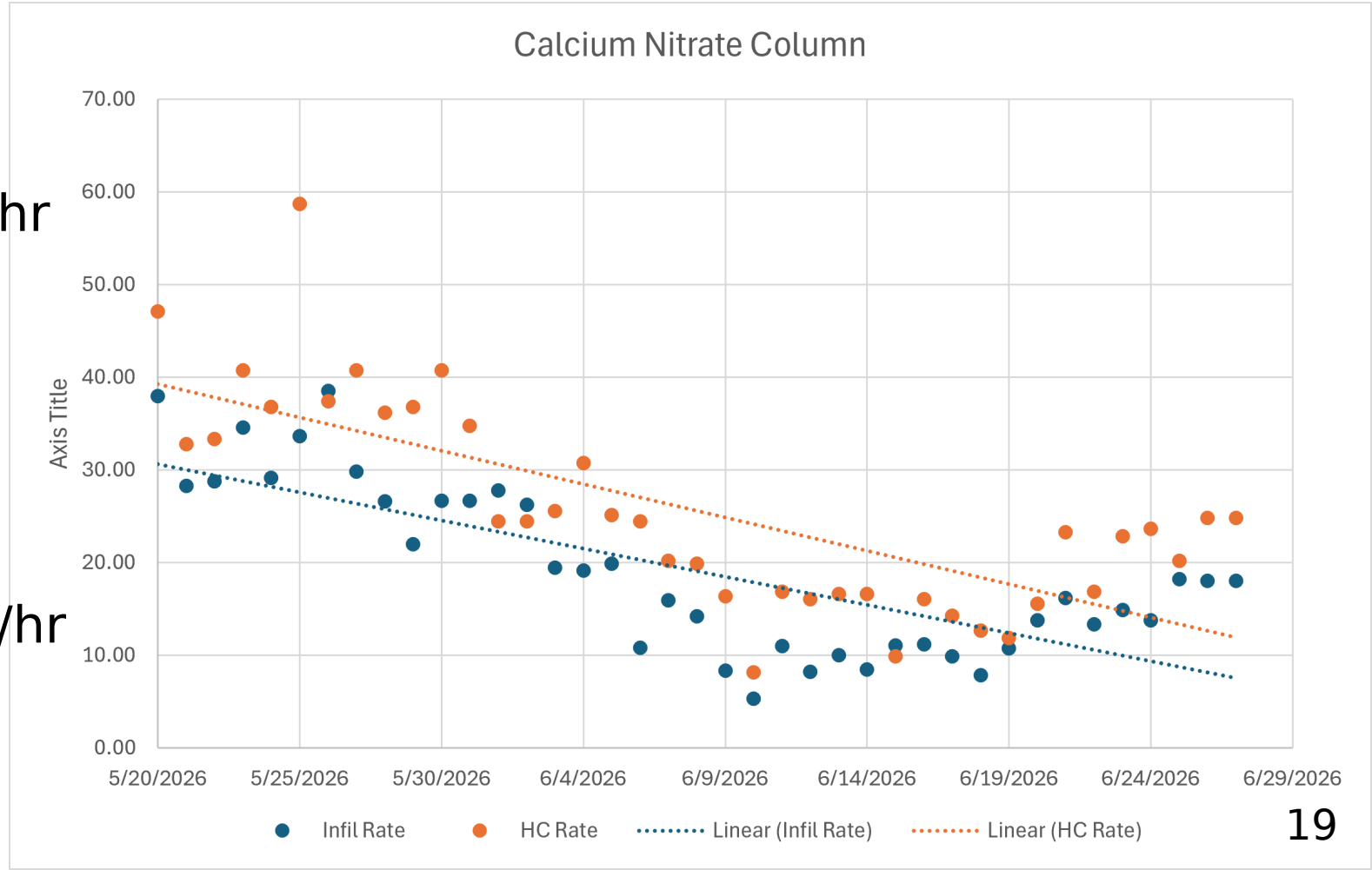
Calcium Acetate Column

- Infiltration Rate
  - Initial: 45 in^3/hr
  - Remediation Day: 21 in^3/hr
  - R. Peak: 35 in^3/hr
  - Final: 22 in^3/hr
- Hydraulic Conductivity
  - Initial: 70 in^3/hr
  - Remediation Day: 29 in^3/hr
  - R. Peak: 42 in^3/hr
  - Final: 29 in^3/hr



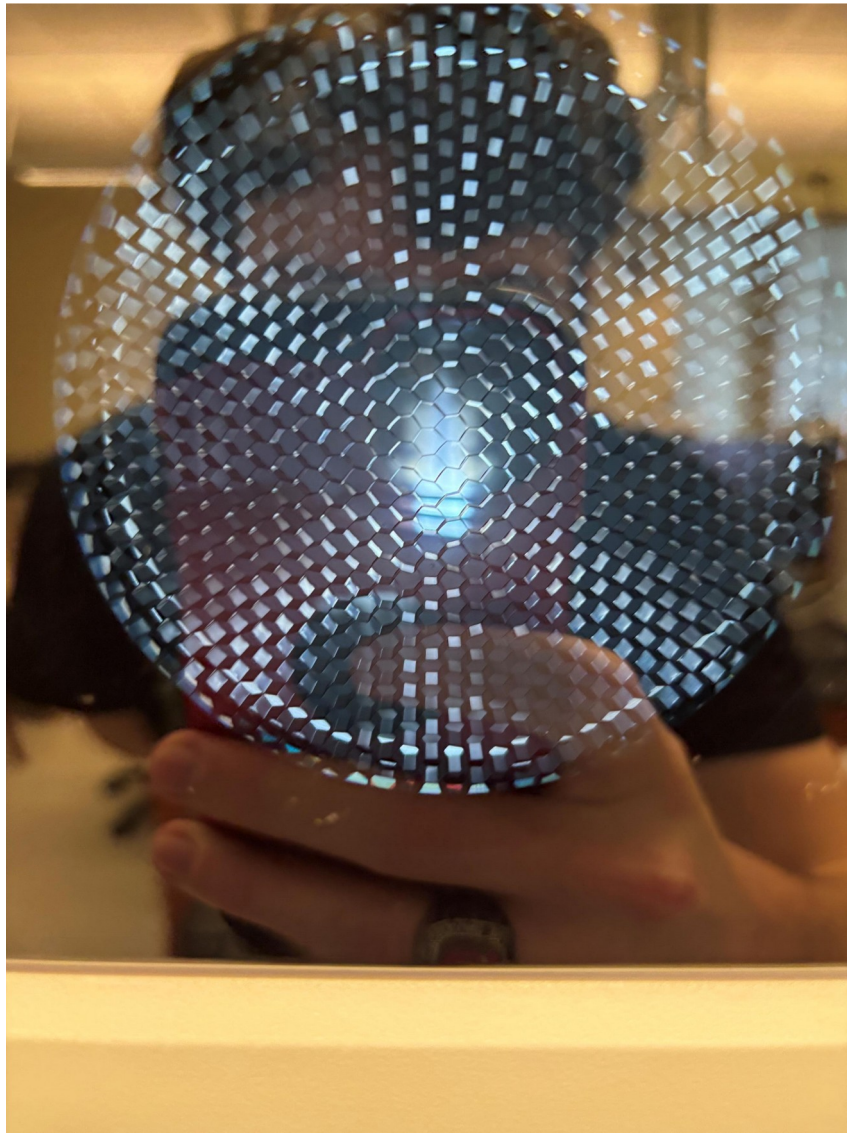
Calcium Nitrate Column

- Infiltration Rate
  - Initial: ~30 in^3/hr
  - Remediation Day: 14in^3/hr
  - R. Peak: 18 in^3/hr
  - Final: 18 in^3/hr
- Hydraulic Conductivity
  - Initial: ~40 in^3/hr
  - Remediation Day: 16 in^3/hr
  - R. Peak: 25 in^3/hr
  - Final: 25 in^3/hr



Column Set 1 Summary

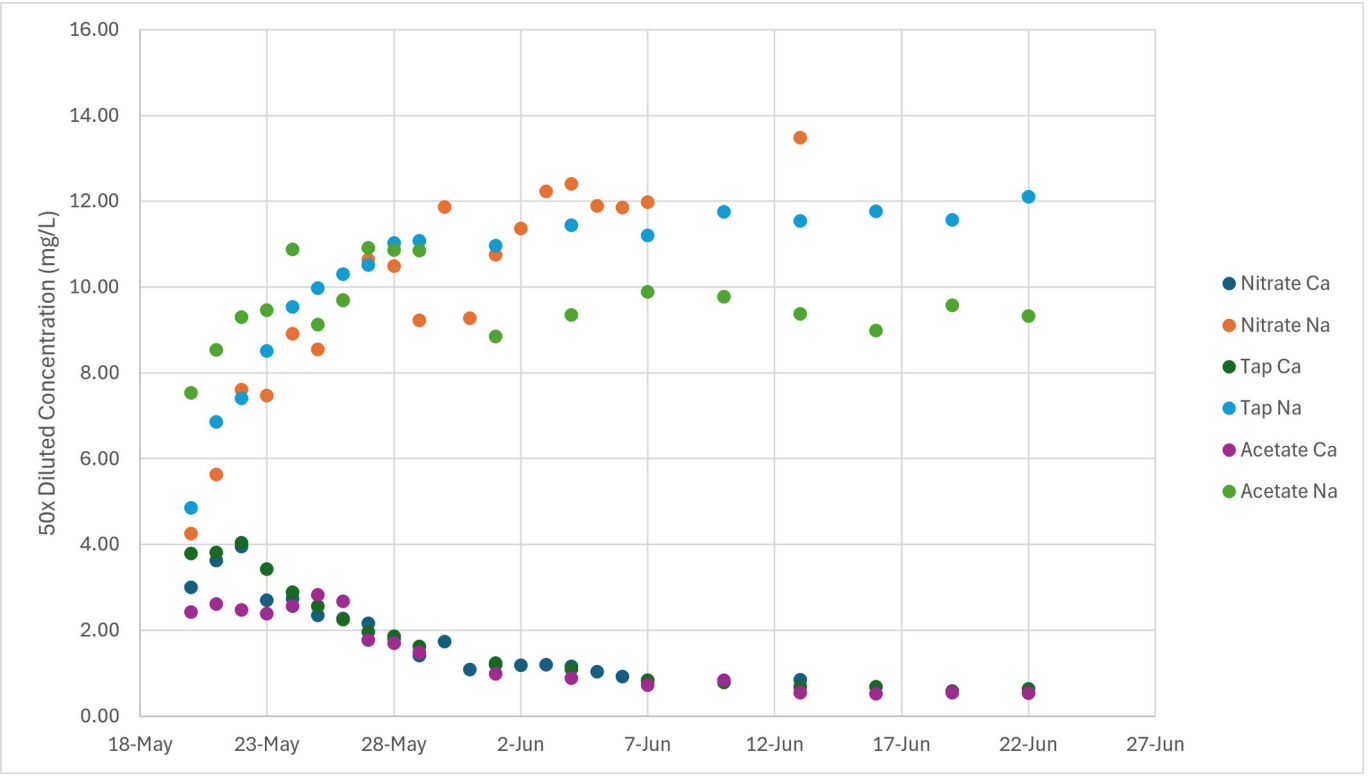
	Tap Control	Calcium Acetate	Calcium Nitrate
IR reduced to	27%	47%	47%
IR restored to	-	78%	60%
Final IR	-	49%	60%
HC reduced to	50%	41%	40%
HC restored to	-	60%	63%
Final HC	-	41%	63%



ICP Data Collection

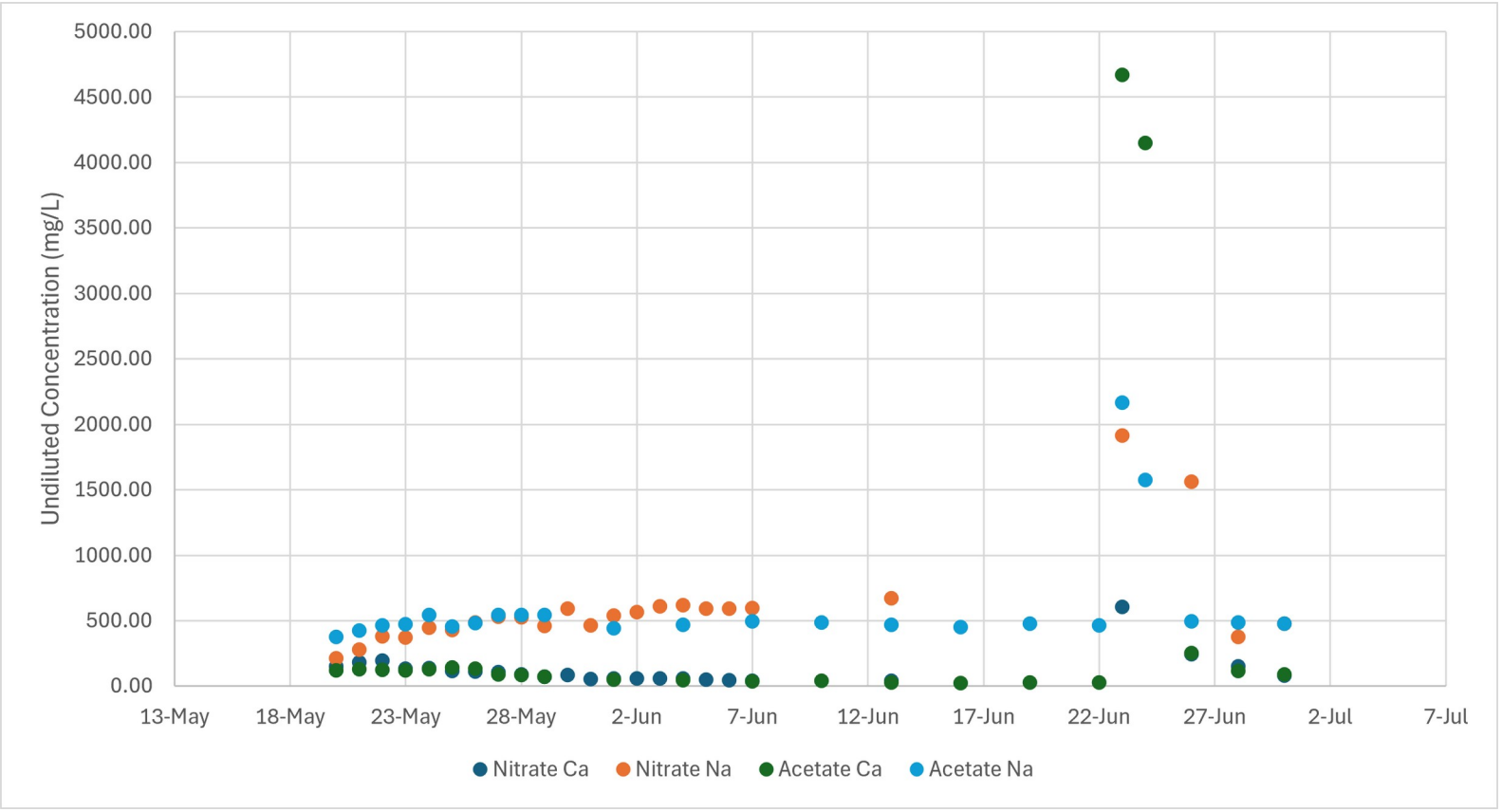
- Column effluent collected daily
- ICP-OES
  - Inductively Coupled Plasma Optical Emission Spectroscopy
- Argon Gas -> Plasma
- Excited atoms emit light

ICP Data - Sodification



- All values are 50x dilution
- Sodium increases
- Calcium decreases

ICP Data Remediation



- All values are undiluted
- 6/24 Nitrate Ca^{2+} value missing
- Tap Data Removed – No Change

Thank you!
Questions?

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