Recovery of Wastewater Nitrogen at Local-Scale: a Feasible Option?

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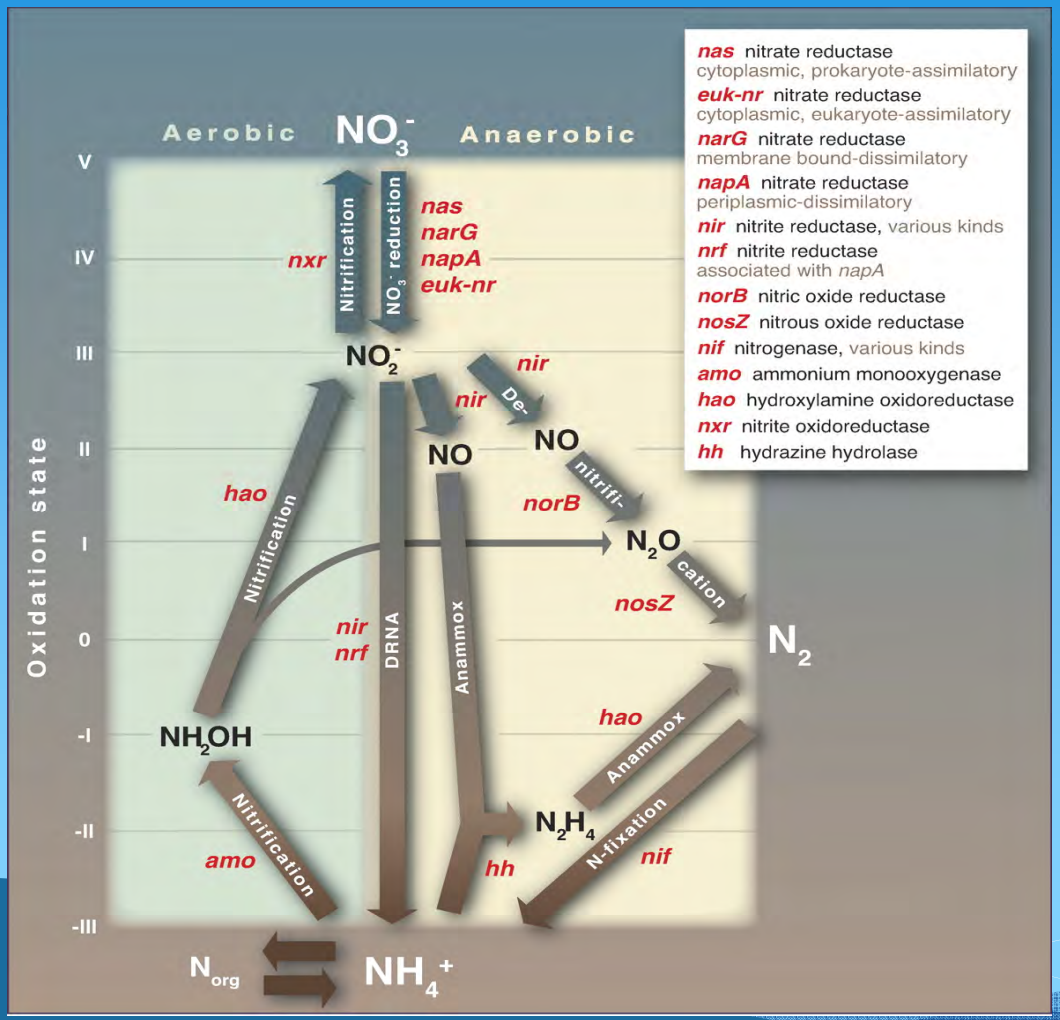
- Washington Suburban Sanitary Commision (WSSC)

Major Nitrogen Pathways



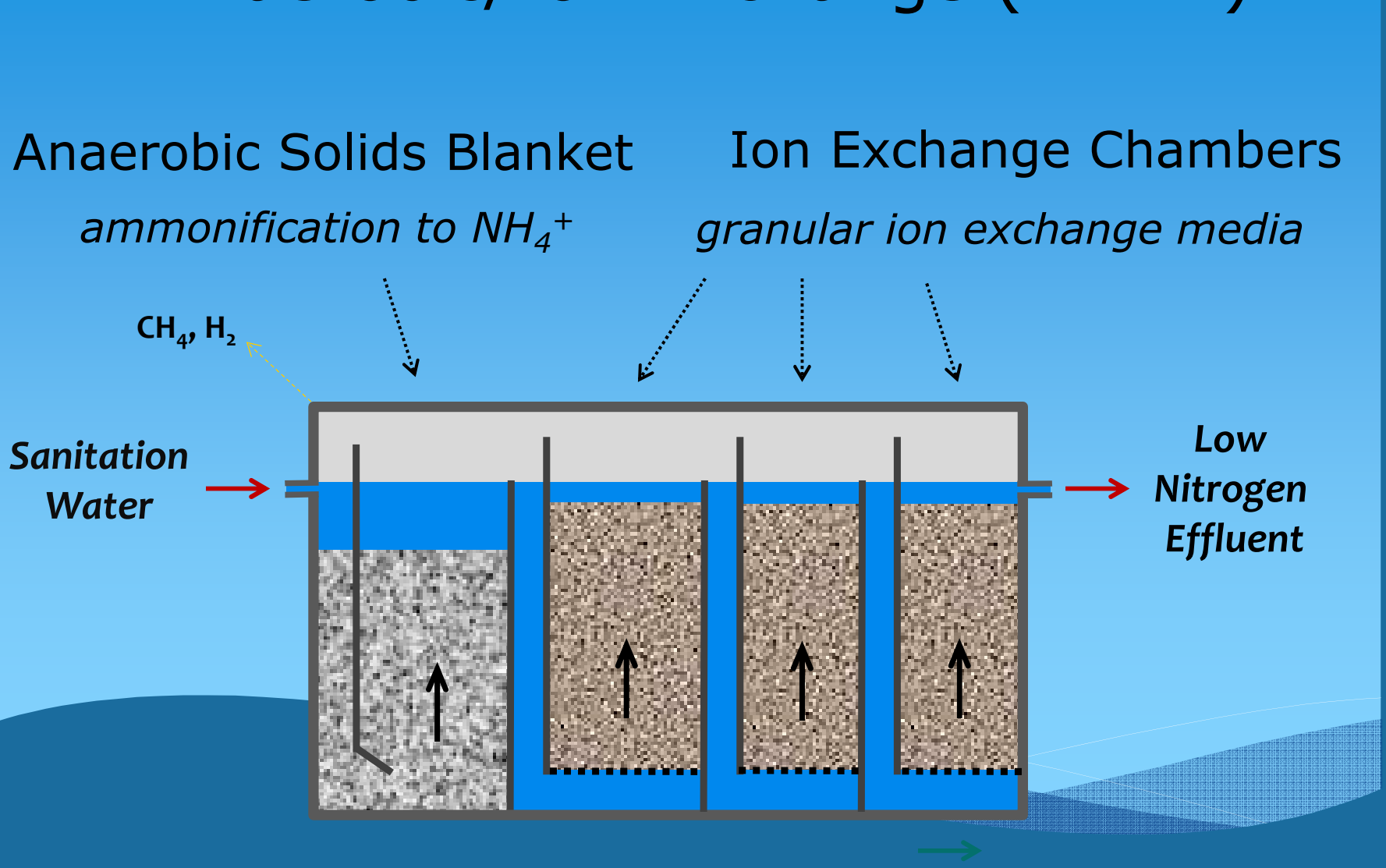
The Evolution and Future of Earth's Nitrogen Cycle, Canfield et al., Science, 2010

Distributed Systems in U.S.

- > 25 million U.S. systems (EPA/625/R-00/008)
- Suffolk Co, Long Island 300,000 units
- Cape Cod 123,000 units
- 125 -500 gpd, 40-80 mg/L TN

Eutrophication

Anaerobic/Ion Exchange (AN-IX)



Anaerobic Treatment (AN)

core resource recovery biotechnology

Hydrolysis ▪ fermentation ▪ ammonification

$$C_{10}H_{19}O_3N \rightarrow CH_3CH_2COO^- + NH_4^+$$

Obligate proton reduction ▪ hydrogenesis

$$CH_3CH_2COO^- + 2\,H_2O \rightarrow CH_3COO^- + 3\,H_2 + CO_2$$

Acetate cleavage ▪ methanogenesis

$$CH_3COO^- + H^+ \rightarrow CH_4 + CO_2$$

Hydrogenotrophic methanogenesis

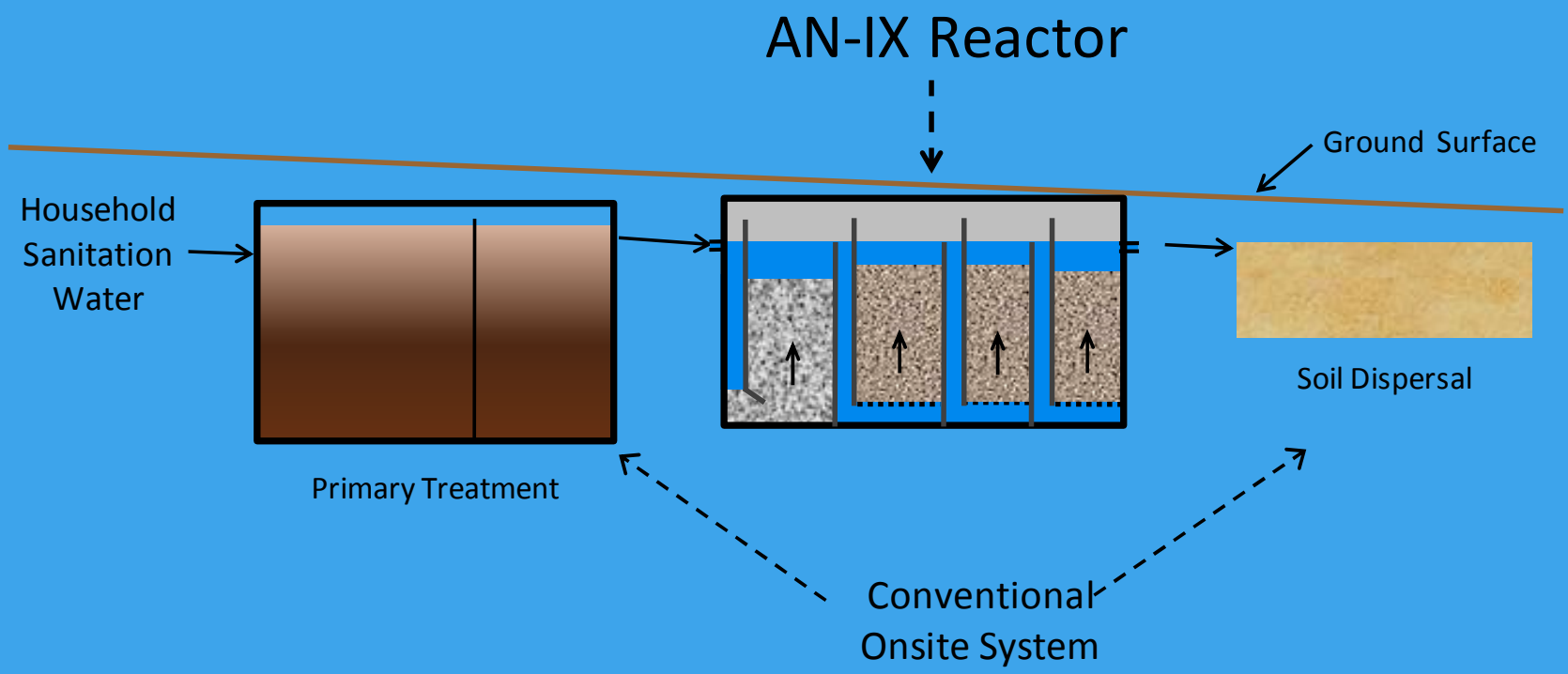
$$4\,H_2 + CO_2 \rightarrow CH_4 + 2\,H_2O$$

Clinoptilolite ZS403H (IX)

- Natural zeolite
- Crystalline, tetrahedral aluminosilicate
- 40 m^2/gram specific surface area
- 1.85 meq./gram CEC
- Effective under anaerobic conditions*

*Water Environment Research

AN-IX Retrofit



AN-IX Nitrogen Recovery

- High total nitrogen recovery >95%
- Simple and reliable
- Local-scale appropriate
- Discontinuous loading
- Seasonal operation
- Suitable for local scale (house, village)

2 Test Sites

Maryland
Mayo Plant

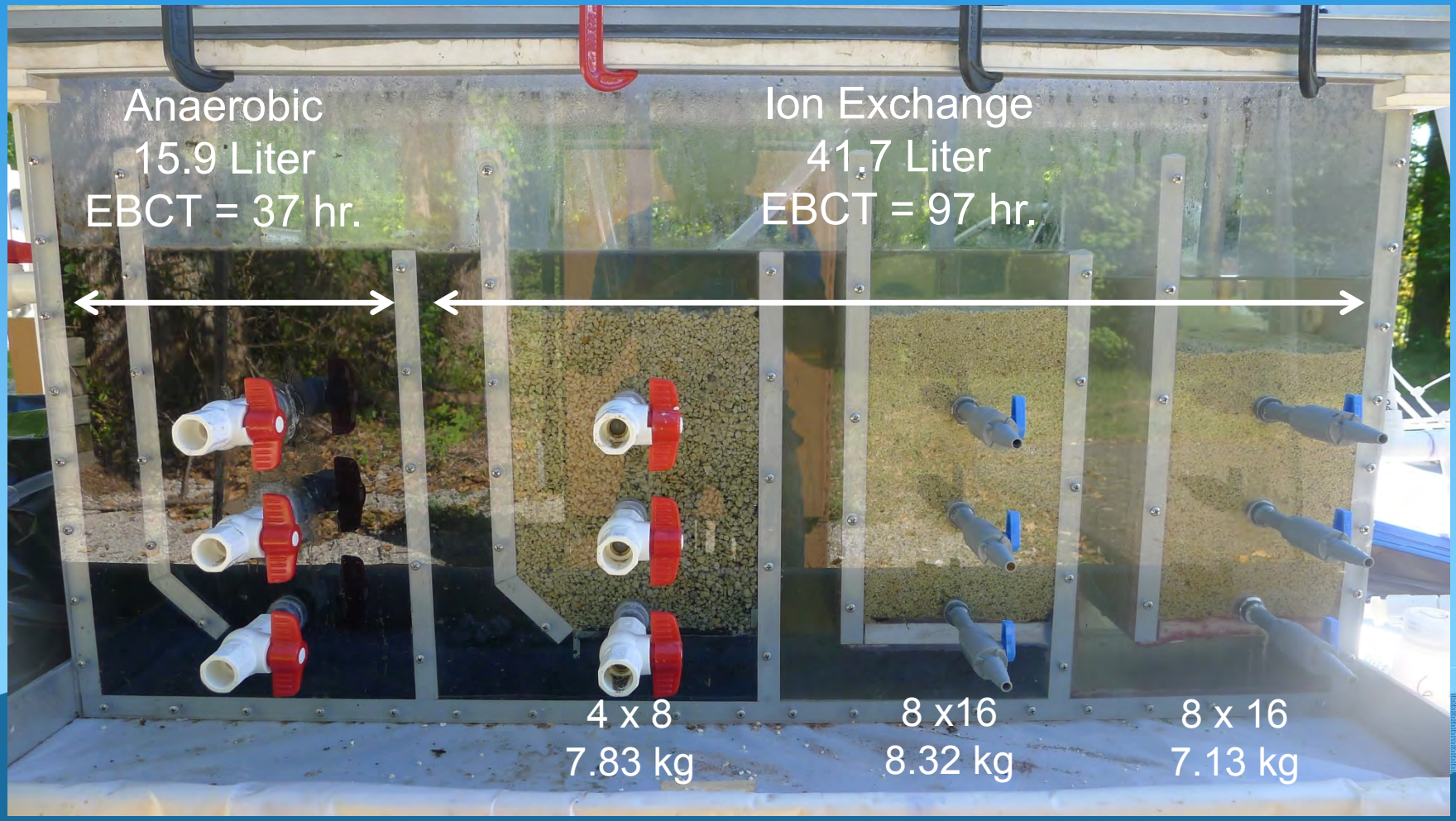
- primary effluent
- 2,800 connections
- ~0.5 mgd

Florida
County Park

- Day use
- 2 bathrooms and ranger residence

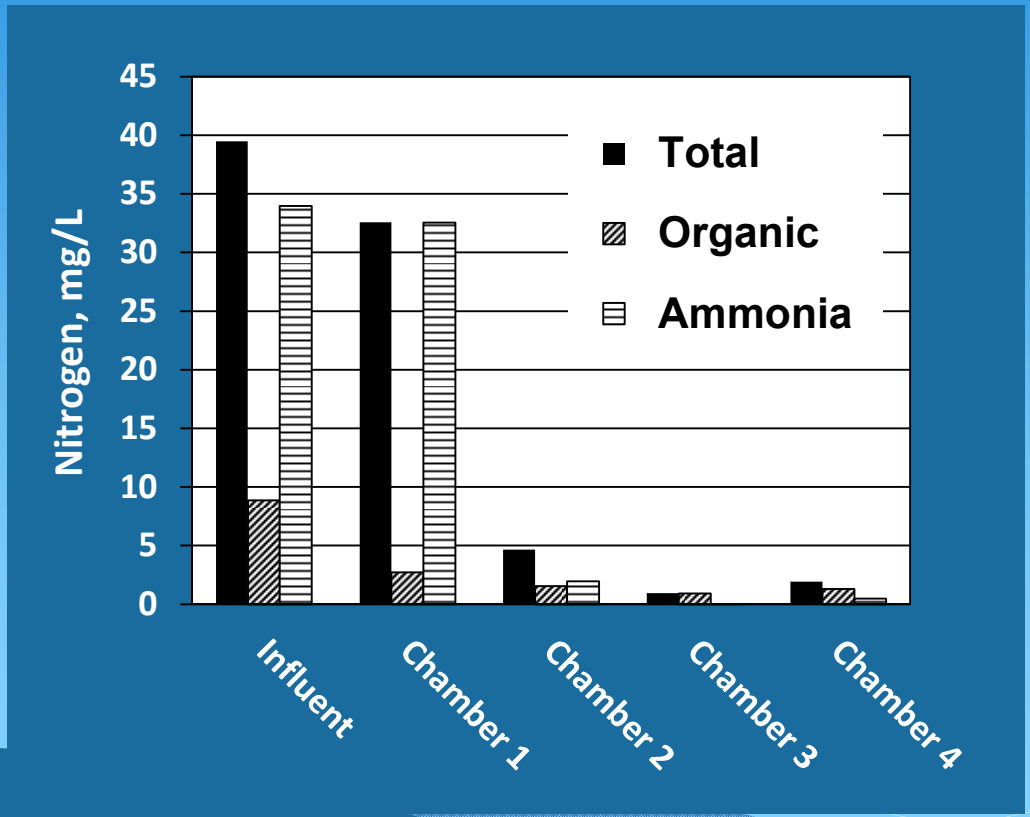
4 Chamber AN-IX Prototype

57.6 liter: liquid empty bed



Mayo pilot

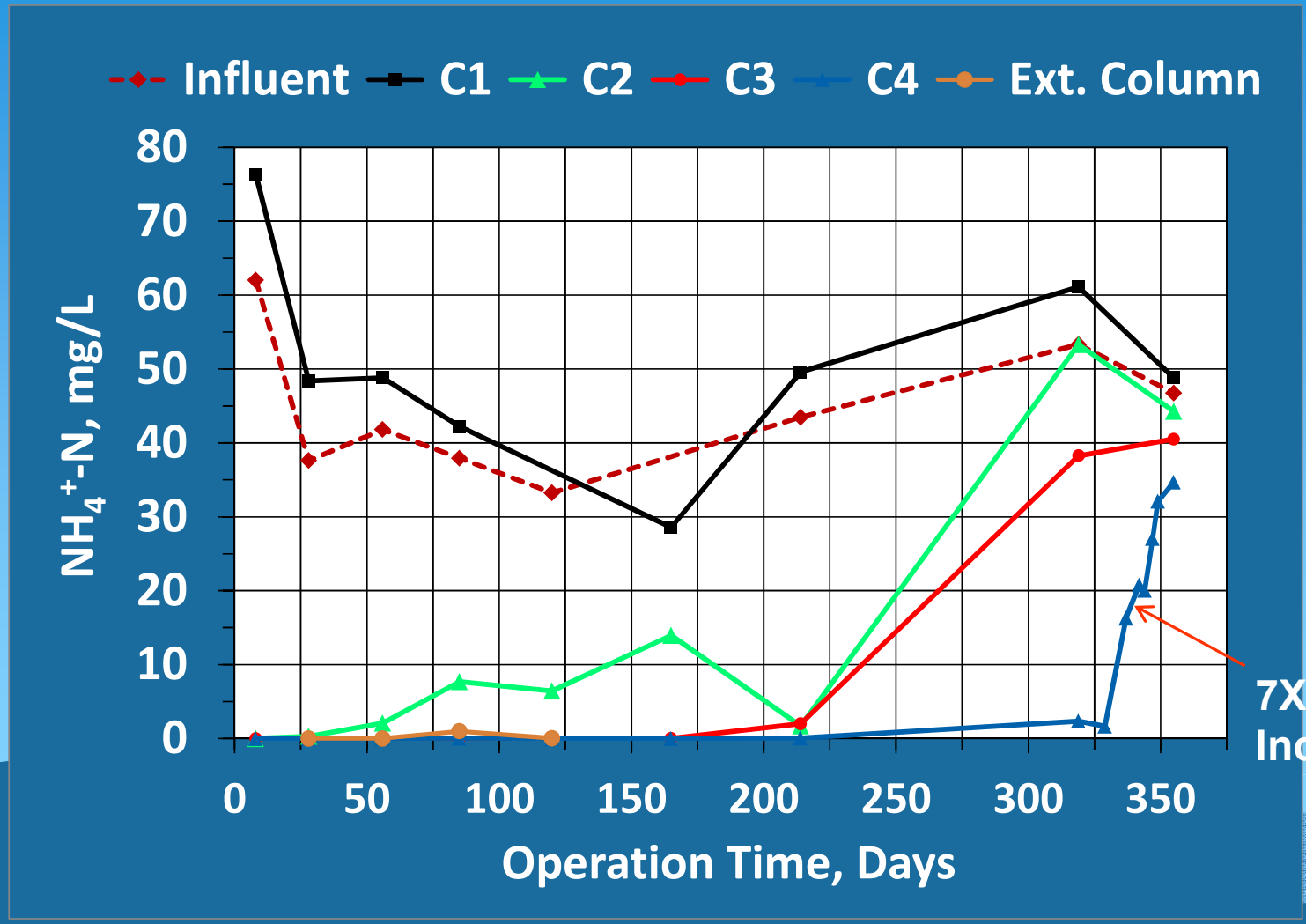
Mean Nitrogen Profiles
Florida AN-IX Day 1-160



Mayo Recovery through Day 214

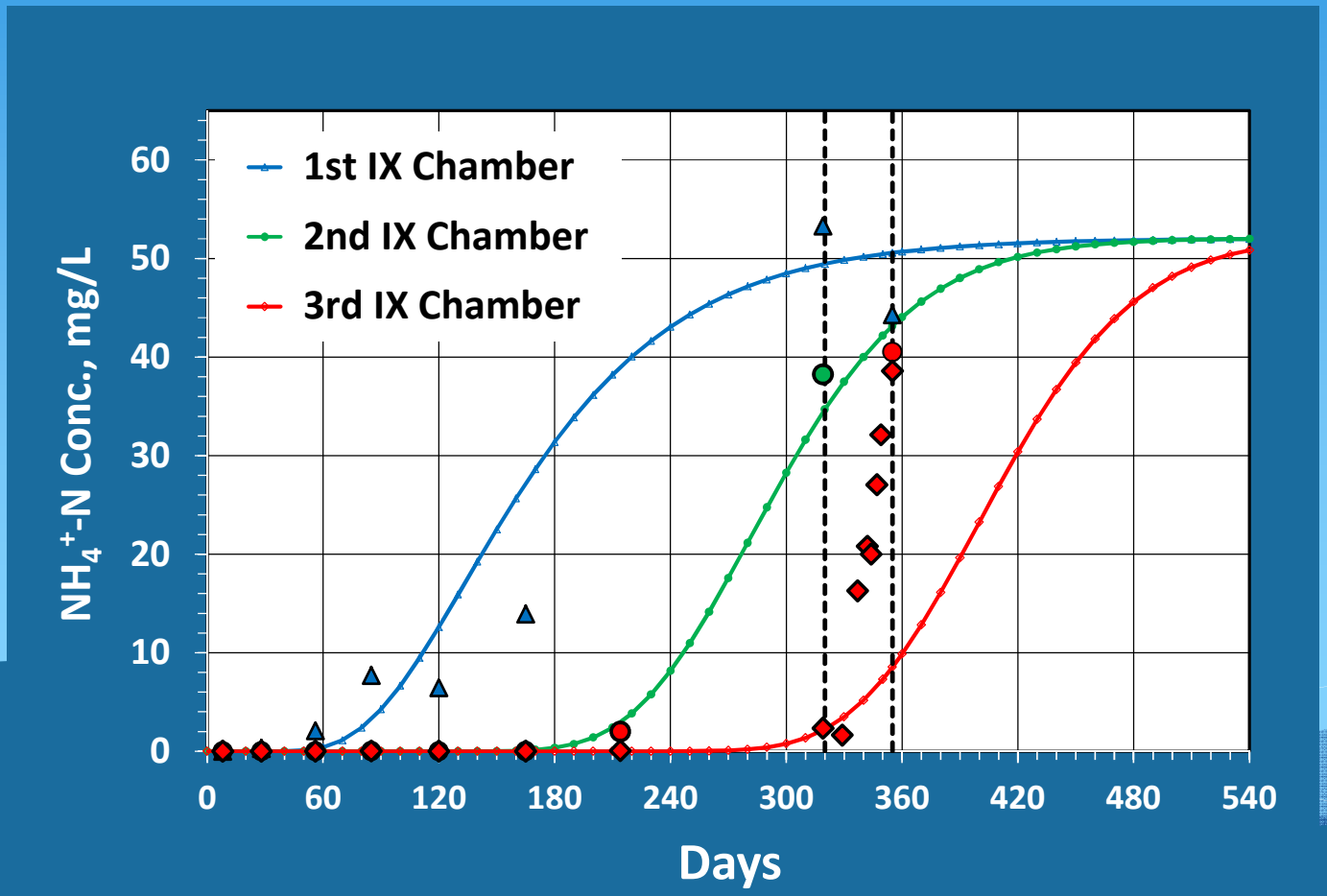
Parameter	Influent, mg/L	Effluent, mg/L	% Recovery
Nitrogen as N	mg/L	mg/L	
Total	54.0	1.3	97.7
Organic	14.3	1.3	91.4
Ammonia	42.7	0.0	99.4
Nitrate+nitrite	0.0	0.0	-
COD	227	93.8	65.5

Mayo NH_4^+ Breakthrough

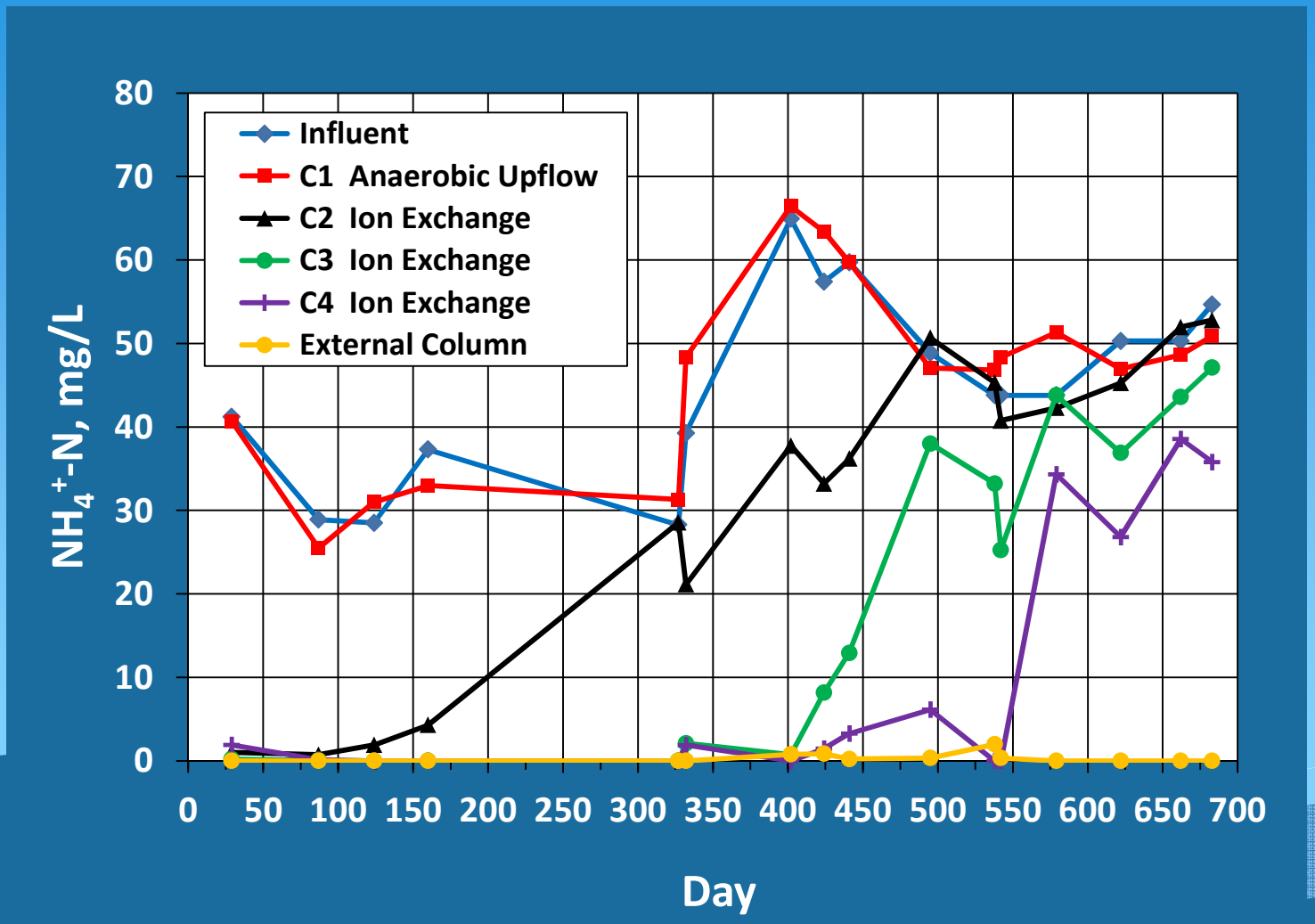


1-D Advection Dispersion Adsorption

$$\frac{dC}{dt} = \frac{1}{R}\left(D\frac{d^2C}{dz^2} - v_o\frac{dC}{dz}\right)$$

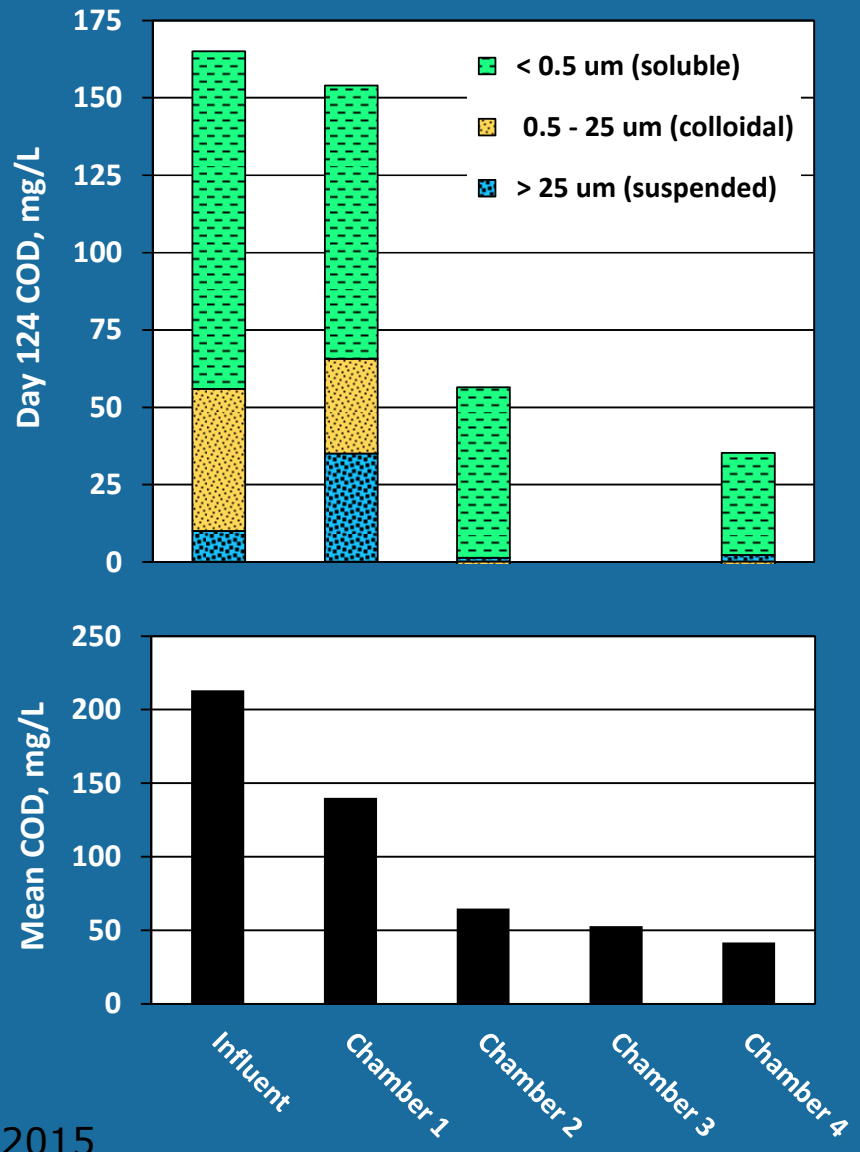


Extended Operation: FL System



Bioresource Technology, 2015

COD Profiles Florida AN-IX



COD Fractionation Day 124

Bioresource Technology, 2015

Typical AN-IX Effluent

- C-BOD_5 < 5
- TSS < 5
- pH 7.1 – 7.4
- ORP < 50
- DON < 2
- Ammonia, nitrate, nitrate ND

NH_4^+-N Adsorption Capacity

	Maryland	Florida
Days Operated	355	662
Flow Rate, L/day	10.2	10.2
NH_4^+ Capacity, mg N/g dw	11.3	13.5

AN-IX Technology Paradigm

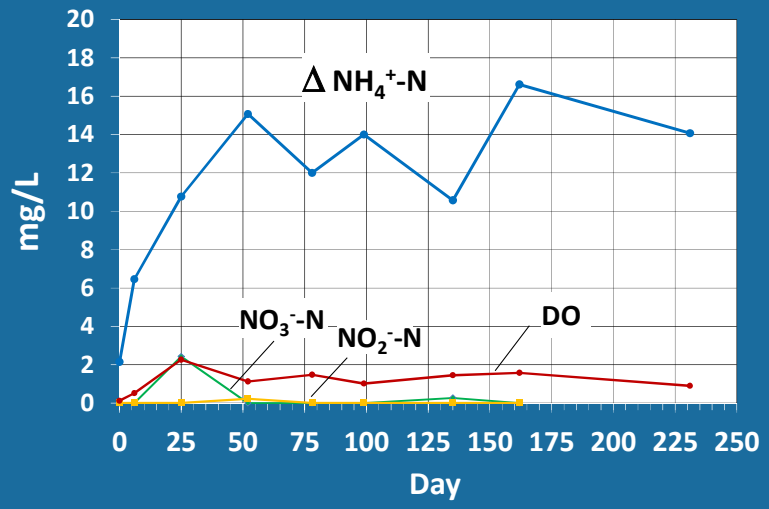
- Prefab module
- SF home: 4 cap., 95% TN removal, 2.5 yr. media replace, 1,400 gal., 44 ft^2
- Operation: Monitor NH_4^+ breakthrough
- Harvest N

Onsite Anammoxozome

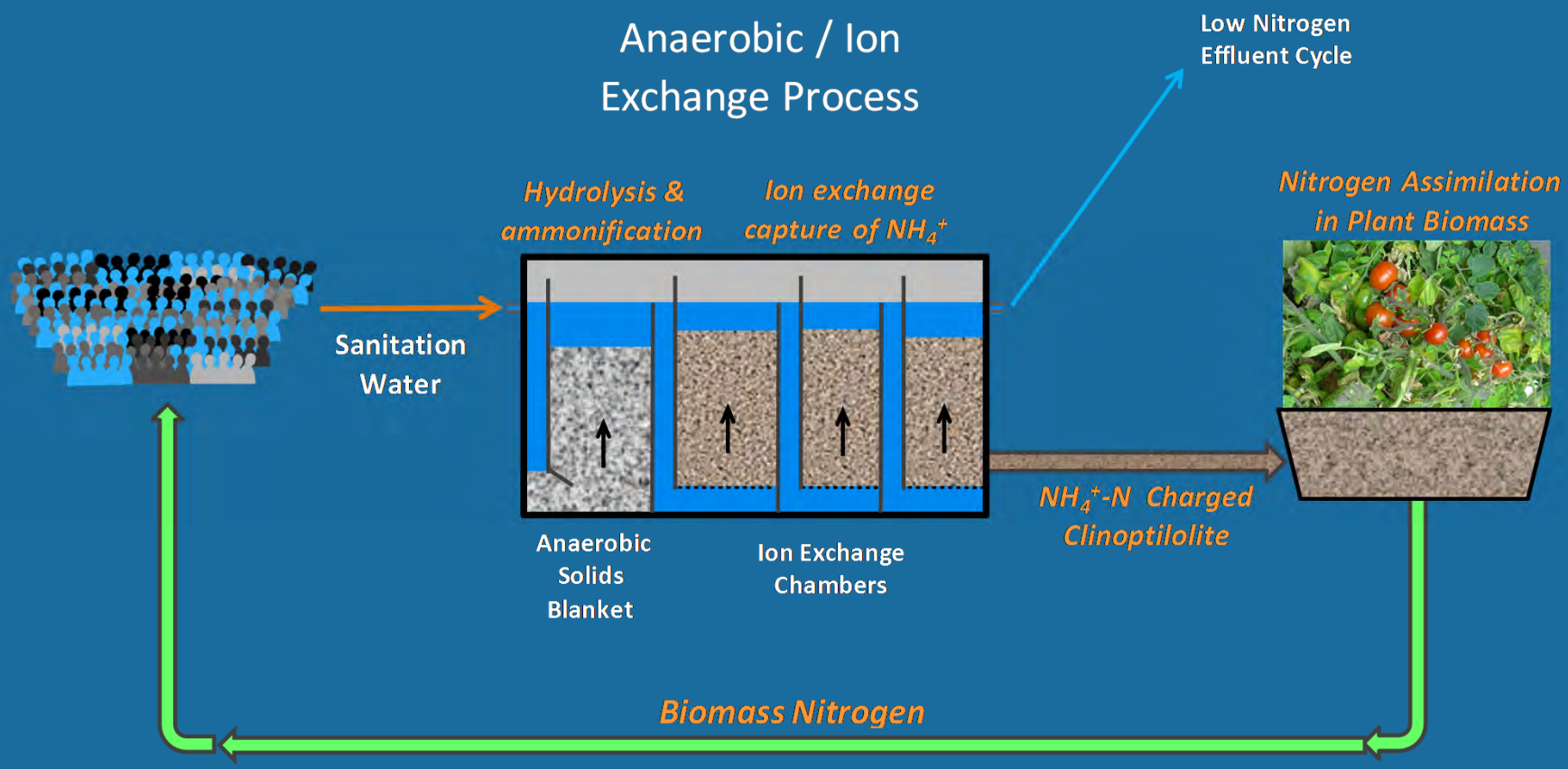
Nitritation + anammox

$$NH_4^+ + 0.75\ O_2 \rightarrow 0.5\ N_2 + 1.5\ H_2O + H^+$$

- Oxygen permeable membrane array
- Lumen air circulation
- Diffusive flux of O_2



Value Proposition:
Local Nitrogen Cycling

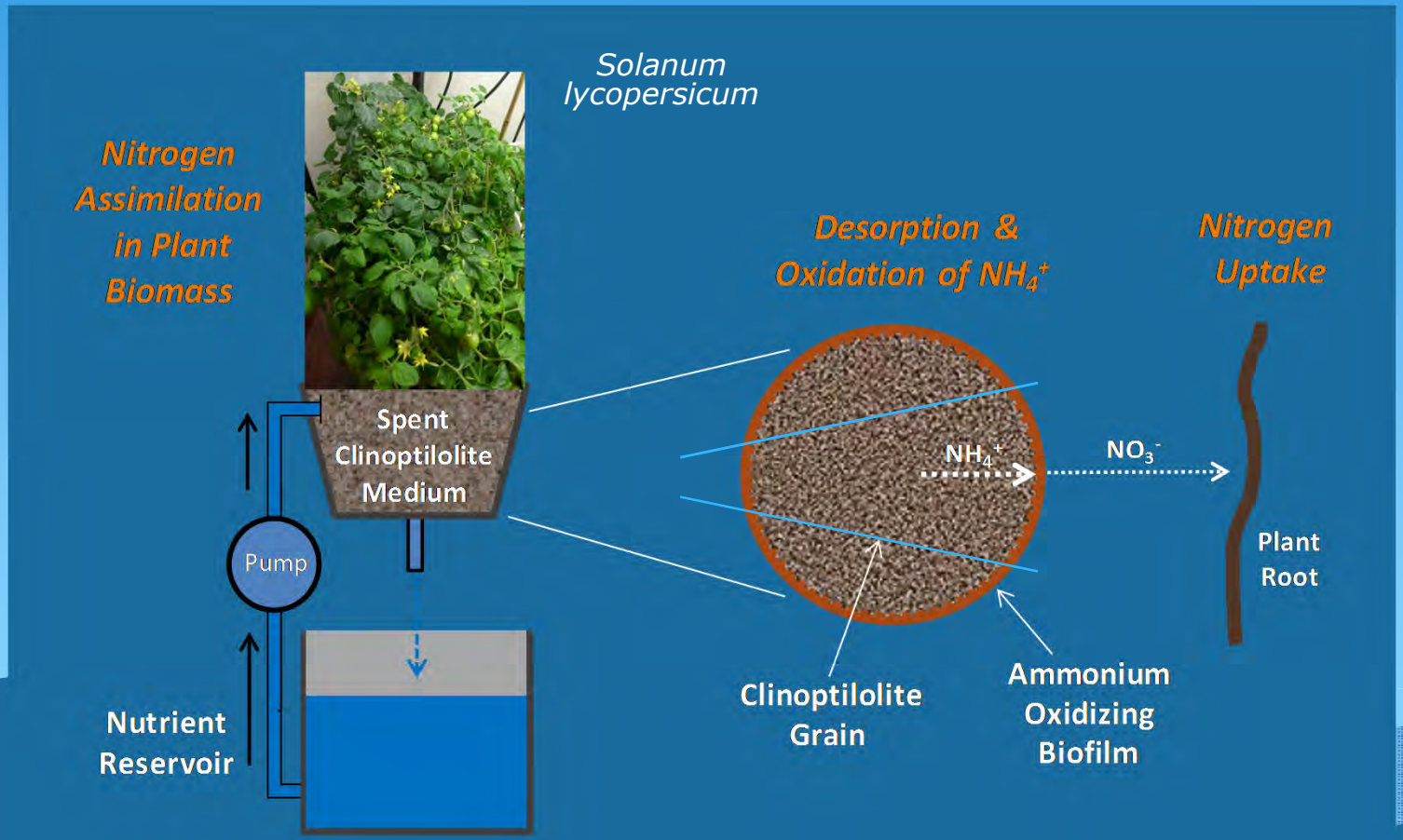


Nitrogen & Media Cycling

- Bioextraction: microbial and plants
- Media regeneration and reuse

Microbial Extraction / Plant Uptake

Fill and Drain Culture



Clinoponics

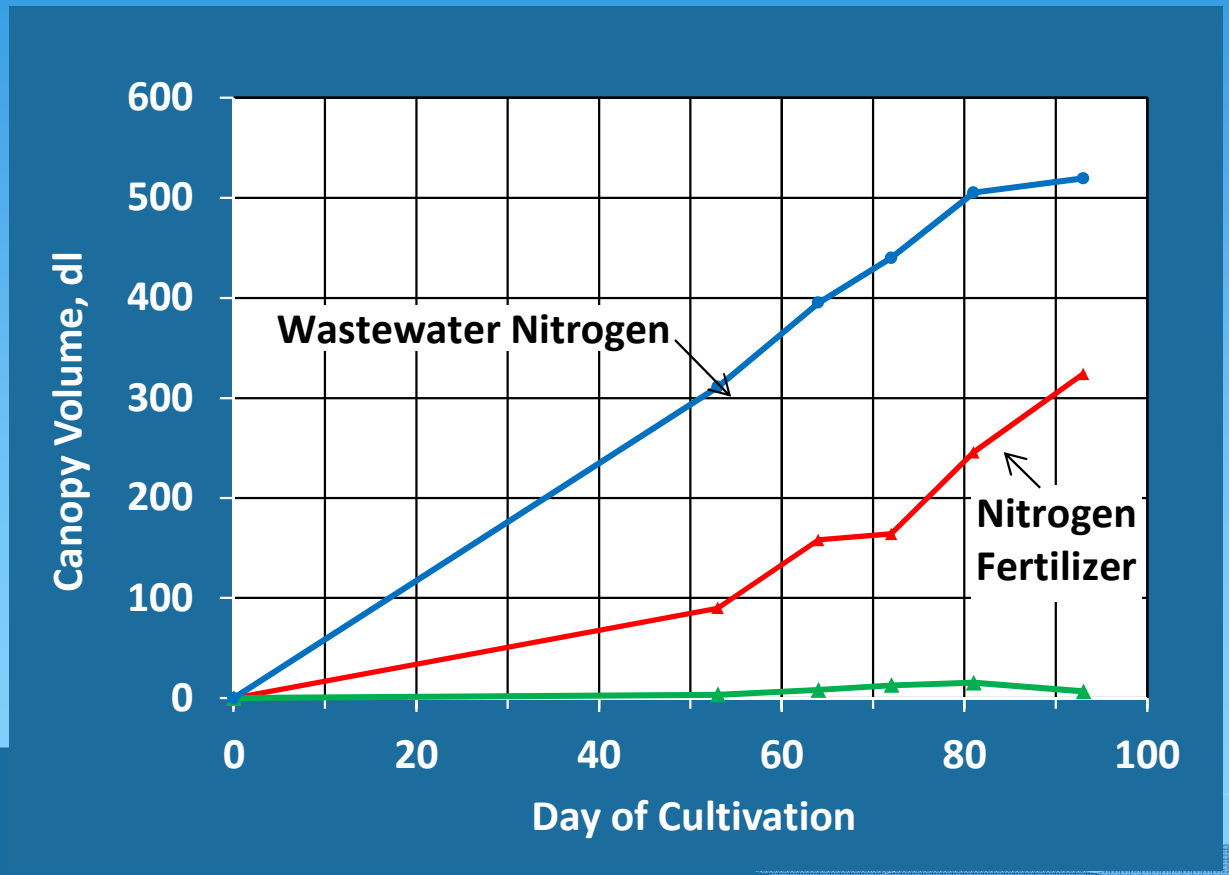
Solanum lycopersicum (cherry tomato)

- Plant growth in granular clinoptilolite
- Fill and drain, 3 cycle/day
- Microbially assisted nitrogen extraction

250 mmol/m^2-sec Photosynthetic Photon Flux @ 12 hour on/off cycle

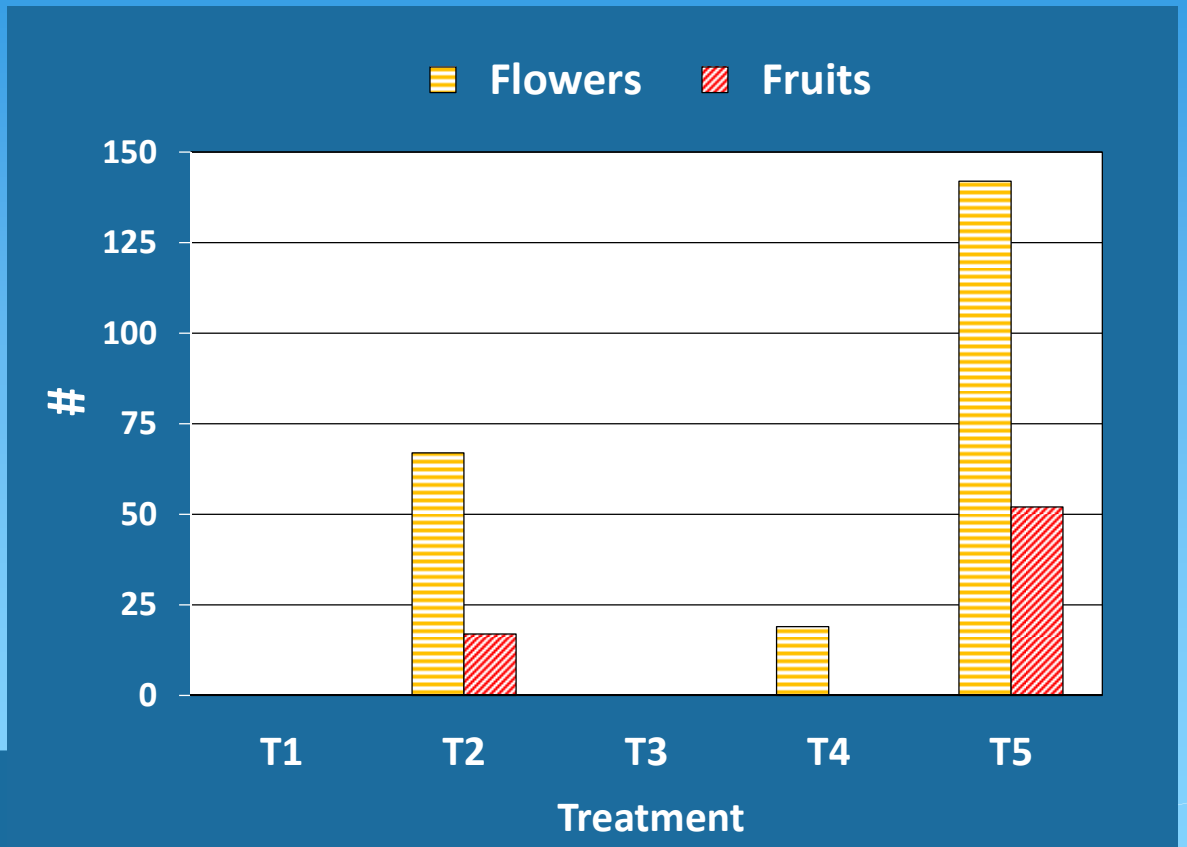
Canopy Volume

Spent clinoptilolite provides all nitrogen for growth



Flower and Fruit

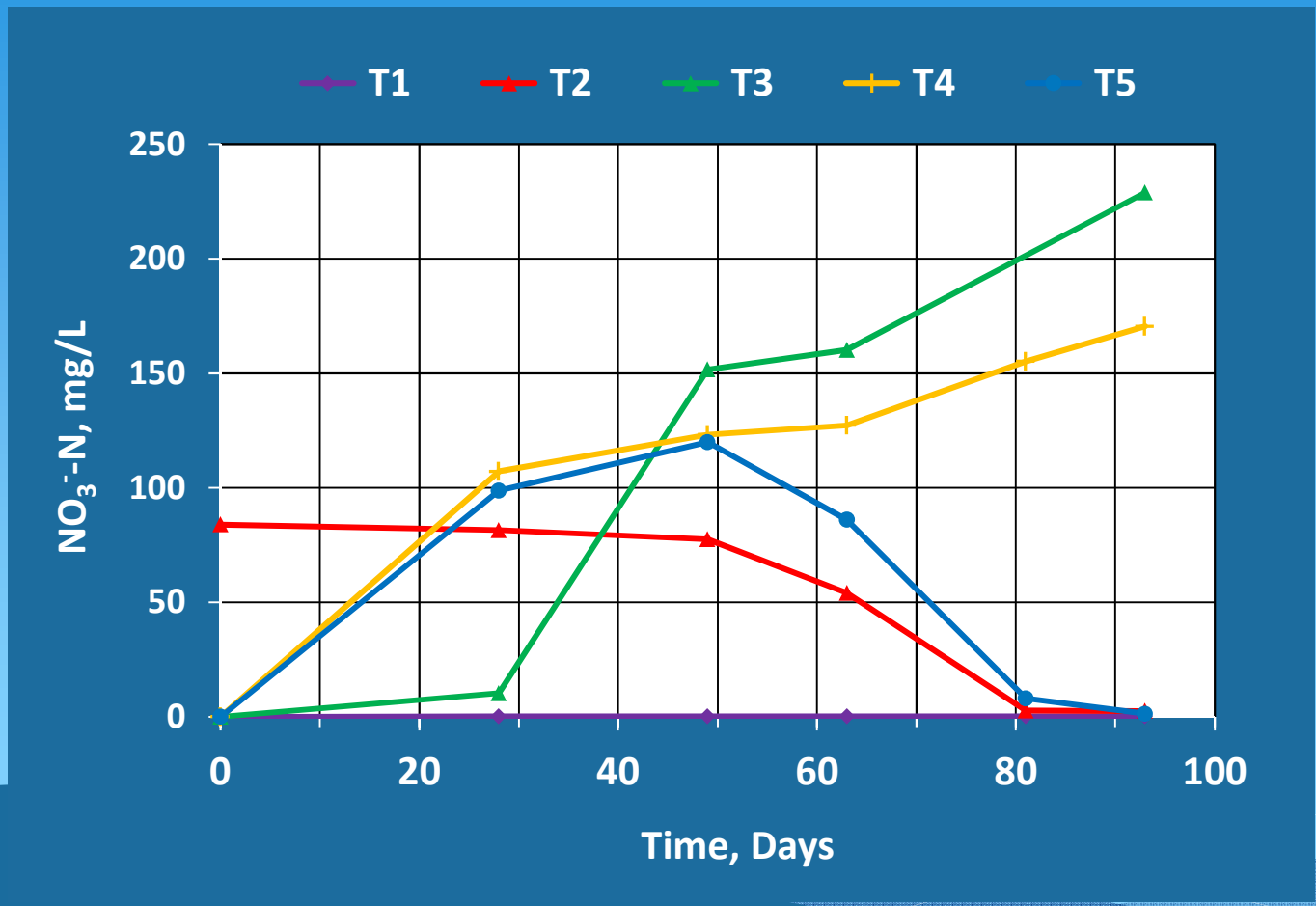
Solanum lycopersicum Day 93



Synthetic nitrogen

Wastewater nitrogen

Bioextraction of NO_3^-



Water Science and Technology, 2015

Urban Eco-Structure

Scale	Nitrogen Load, lb/year	Clino Replace, years	AN-IX Plan Area, ft^2
Single Sub- Urban Residence	36	2.5	35
16-Unit Complex	461	0.30	158

Prognosis

- Local recovery of > 95% Nitrogen
- Appropriate technology
- Local scale recyling
- Urban applications

Thank you

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