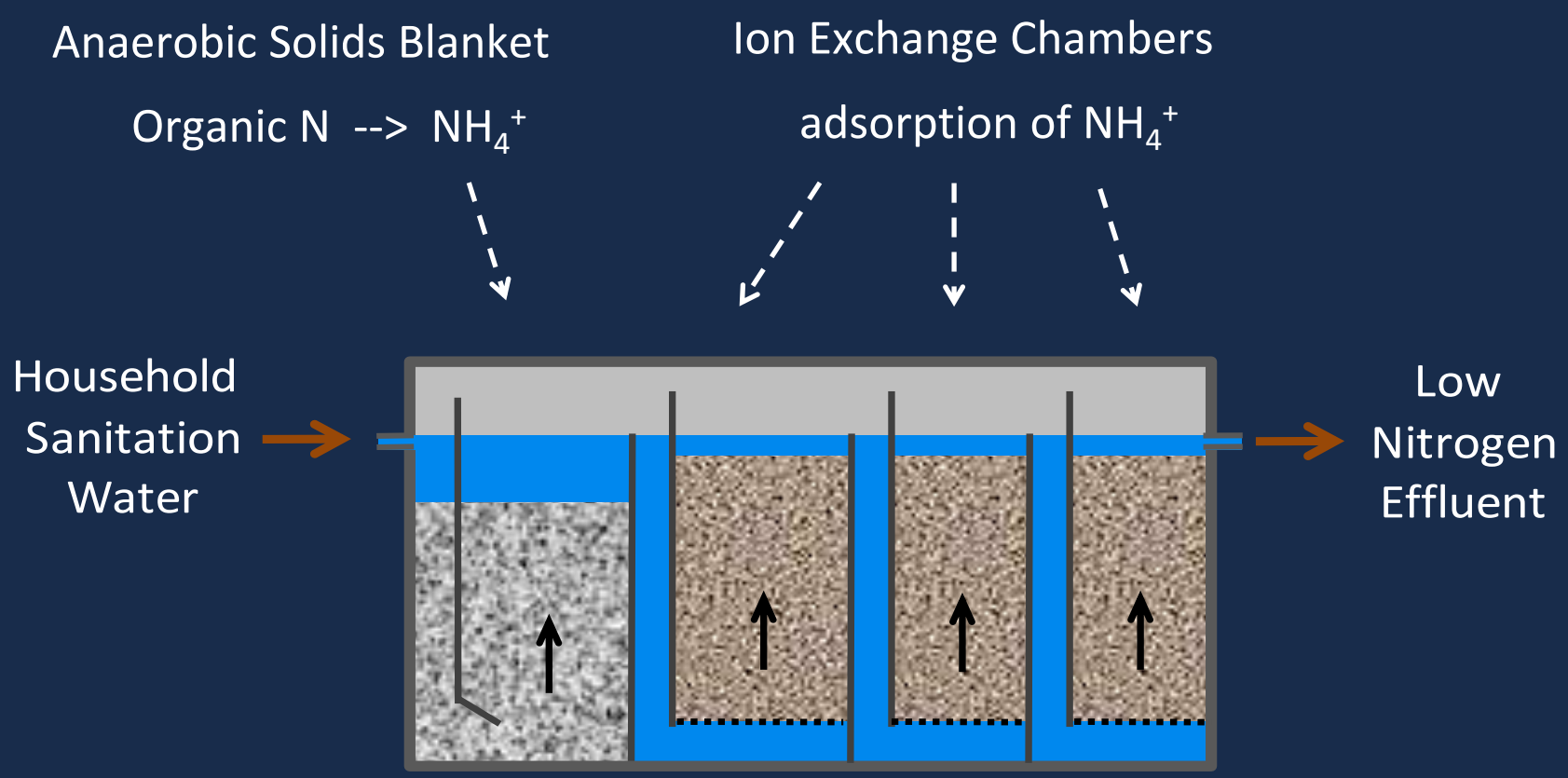
AET Tech

Nitrogen Removal from Wastewater
Ion Exchange Sorption & Regeneration

Dr. Daniel Smith, P.E., BCEE

Point-of-generation nitrogen recovery

Anaerobic/Ion Exchange (AN-IX)



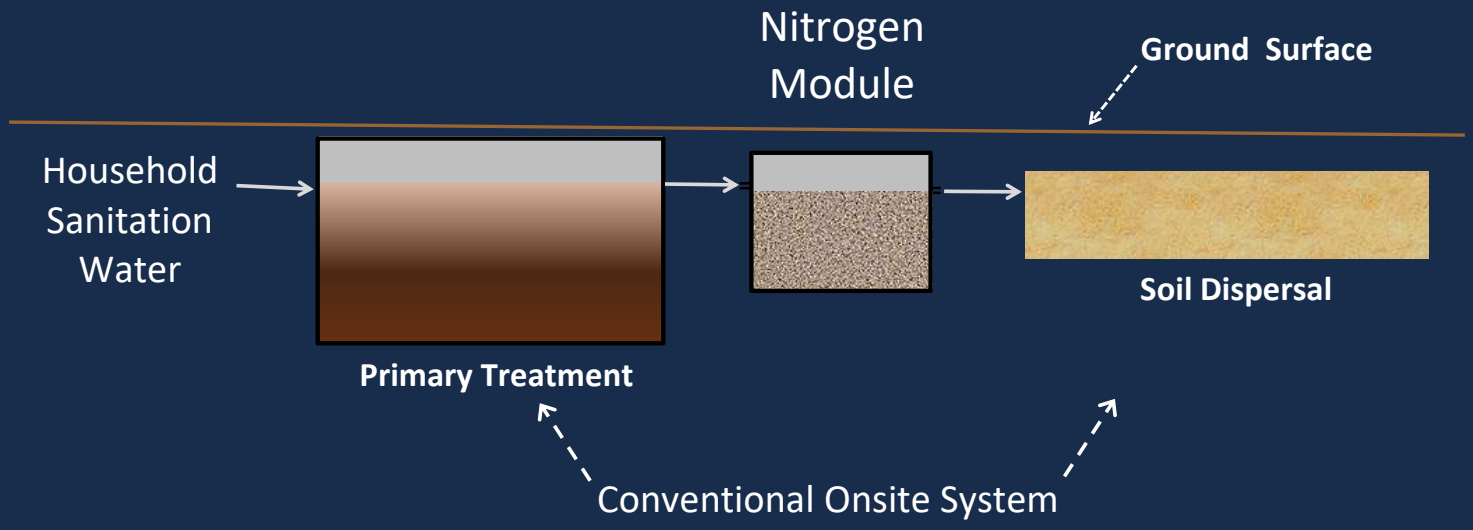
Clinoptilolite NV-Na (IX)

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

Water Environment Research, 2015

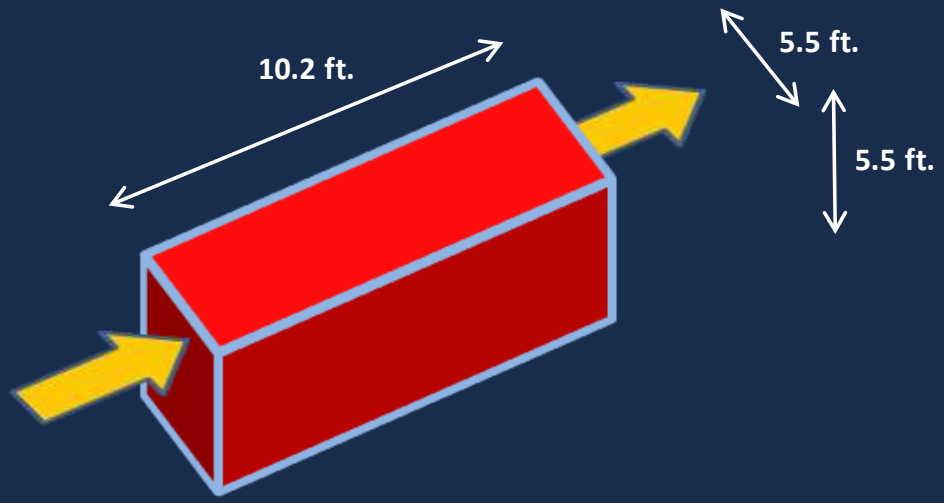
Value Proposition

- easy to install, low O&M
- passive operation
- reliable & low-cost
- achieve objectives

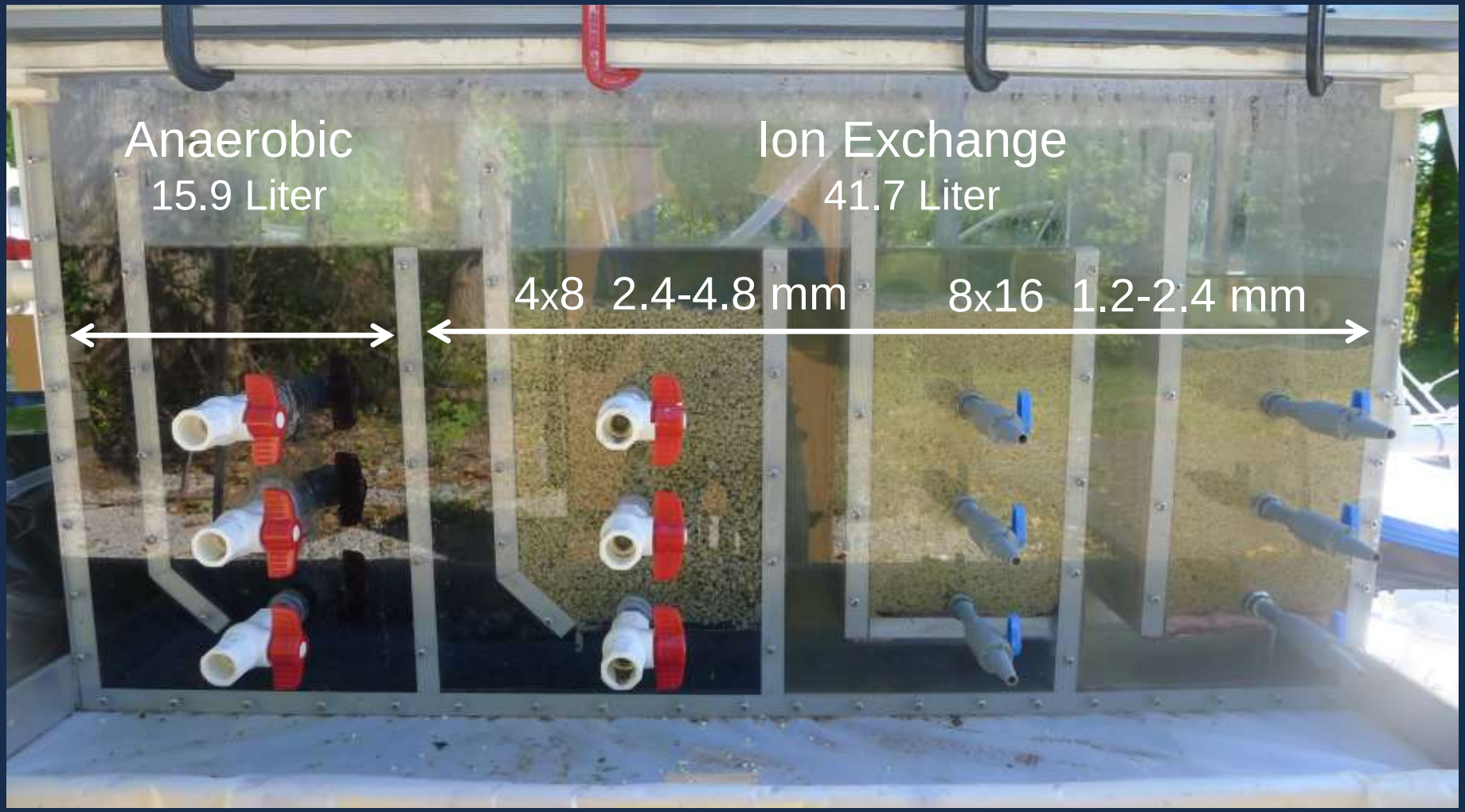


AN-IX Unit

2.5 year longevity for 4 people



Field Prototypes



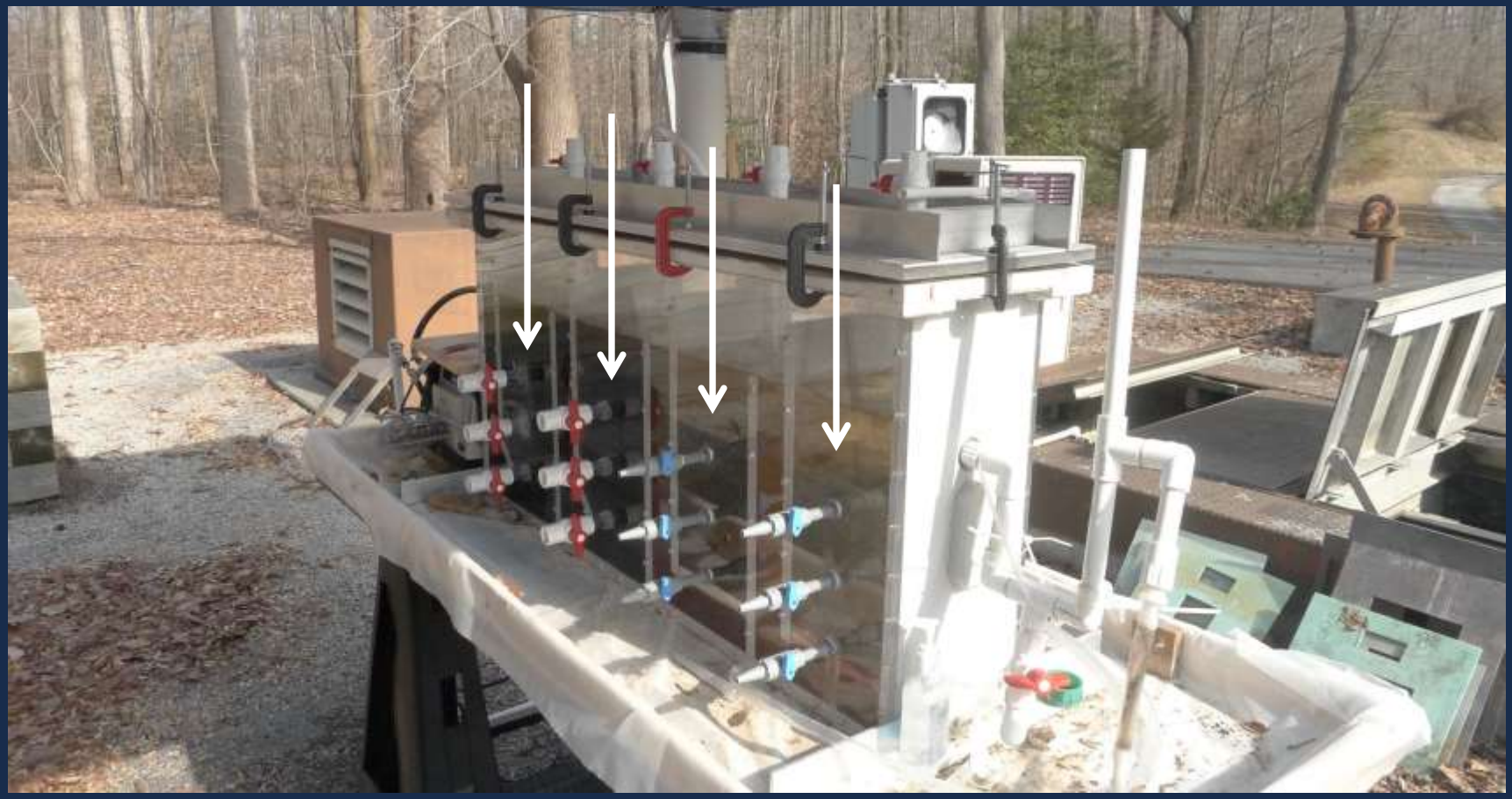
Field Operation 44-78°F

AN-IX Performance

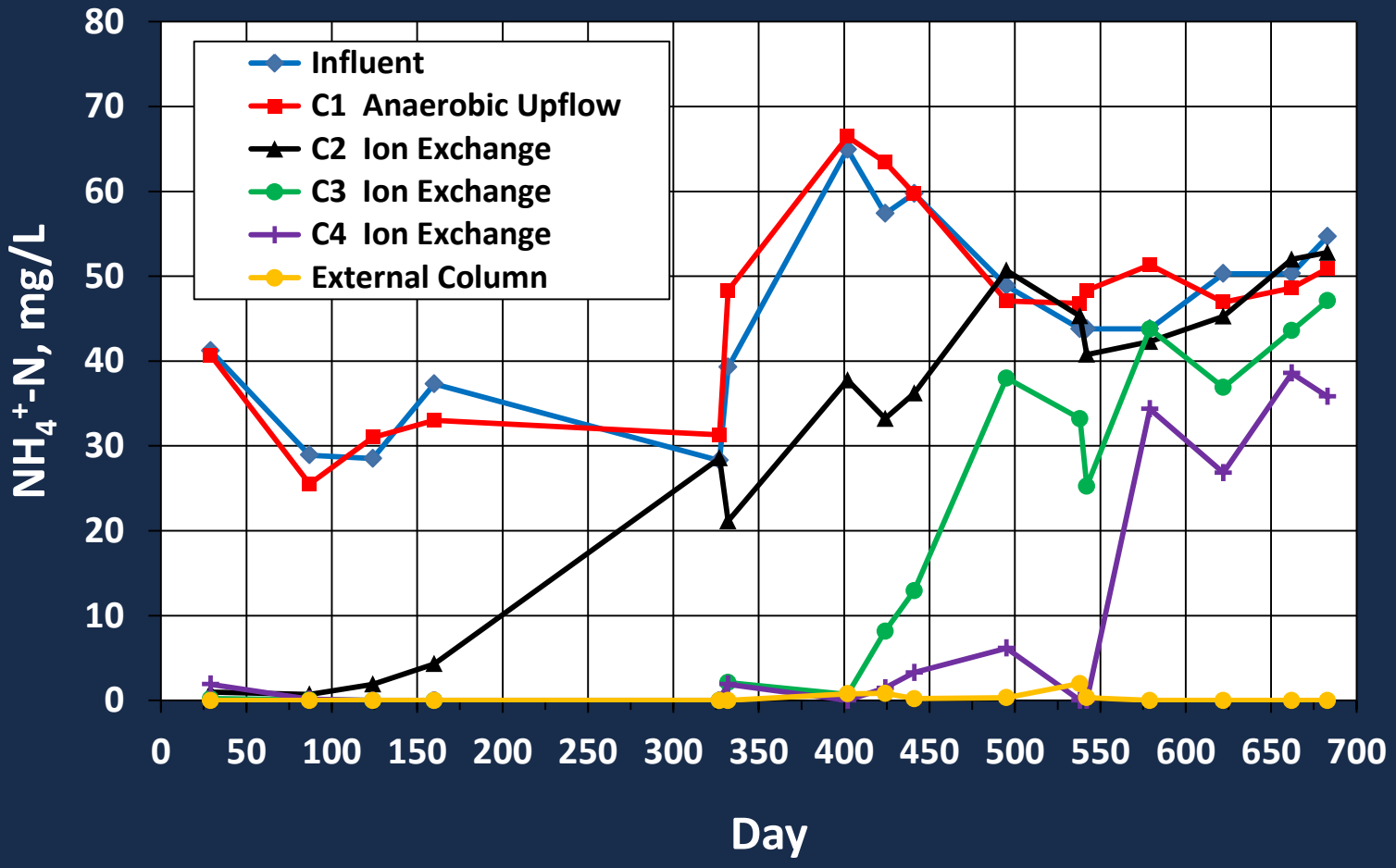
Maryland	Influent, mg/L	Effluent, mg/L	% Removal
Nitrogen as N	mg/L	mg/L	
Total	54.0	1.3	97.7
Organic	14.3	1.3	91.4
Ammonia	42.7	0.0	99.4
Nitrate+nitrite	0.0	0.0	-
COD	227	93.8	65.5

Florida	Effluent, mg/L
C-BOD_5	< 5
TSS	< 1

Monitoring

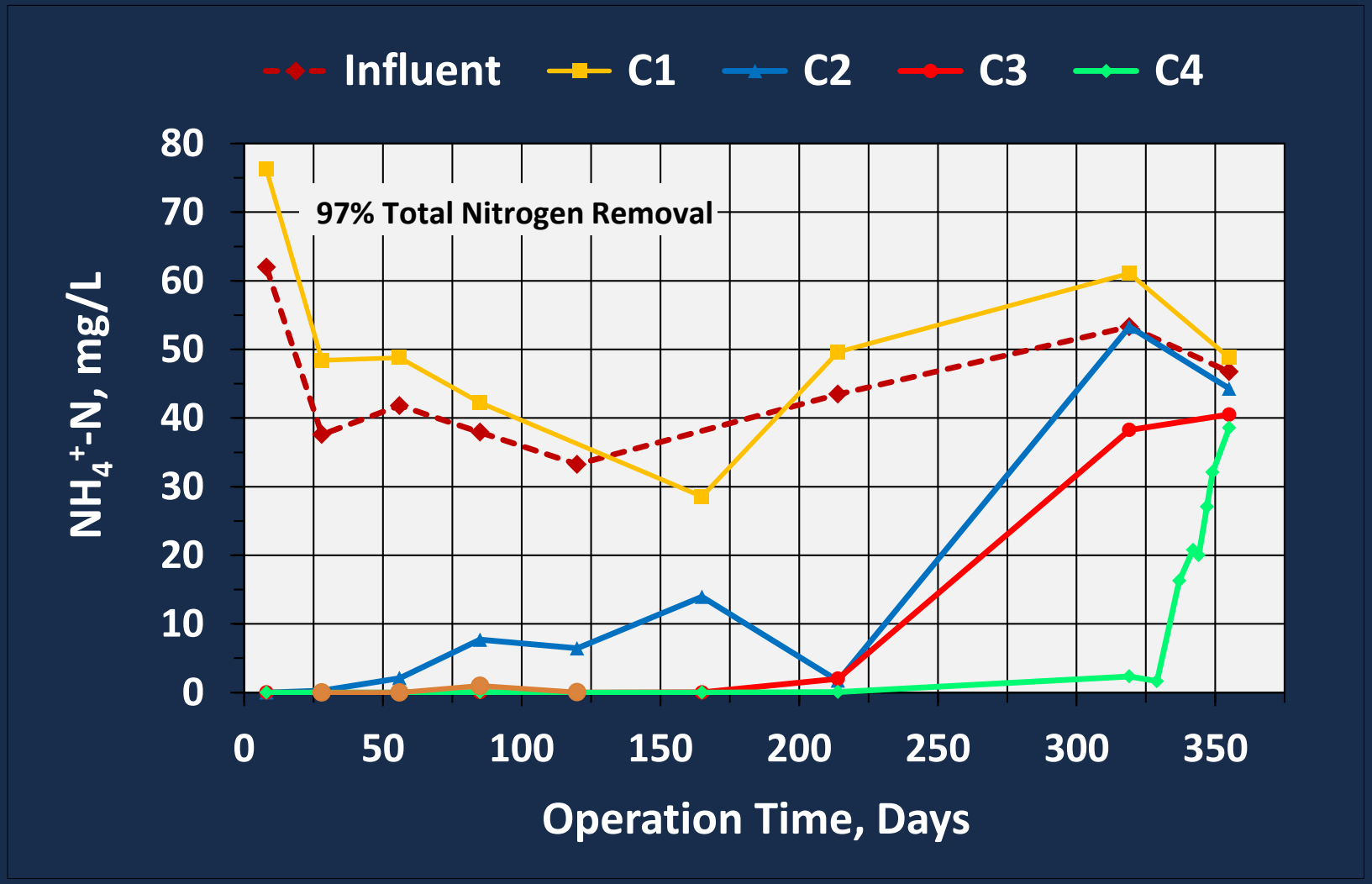


NH_4^+ Profiles- Florida

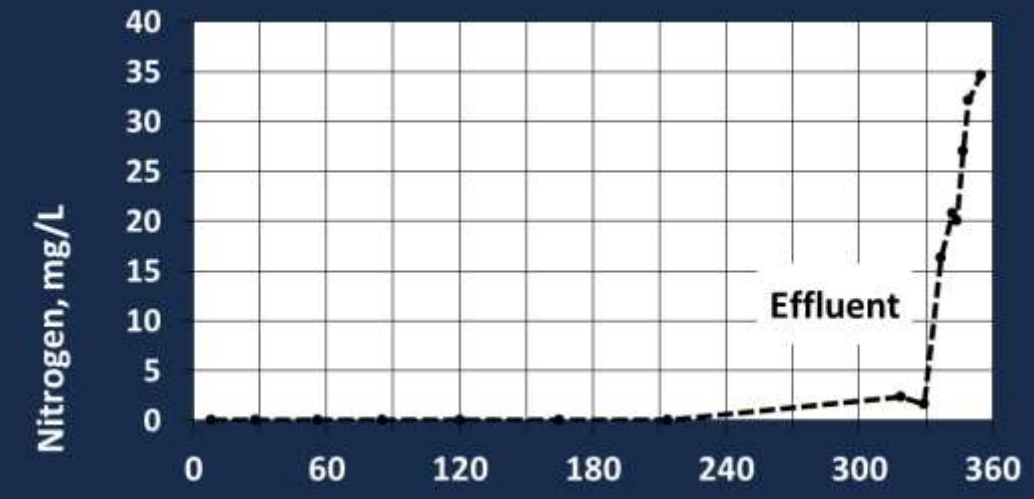


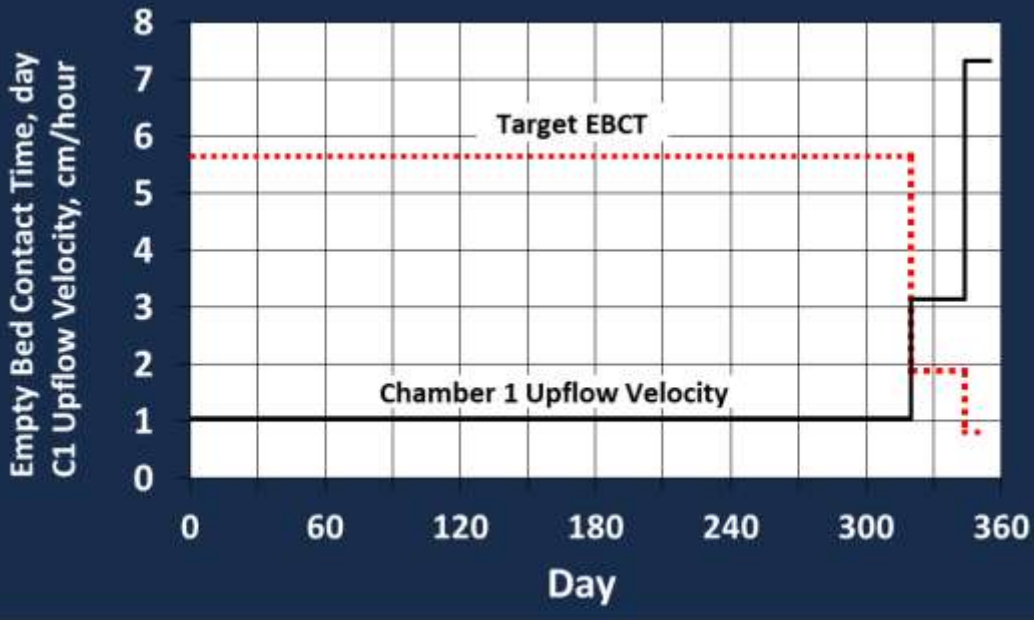
*Bioresource Technology, 2015

NH_4^+ Profiles- Maryland



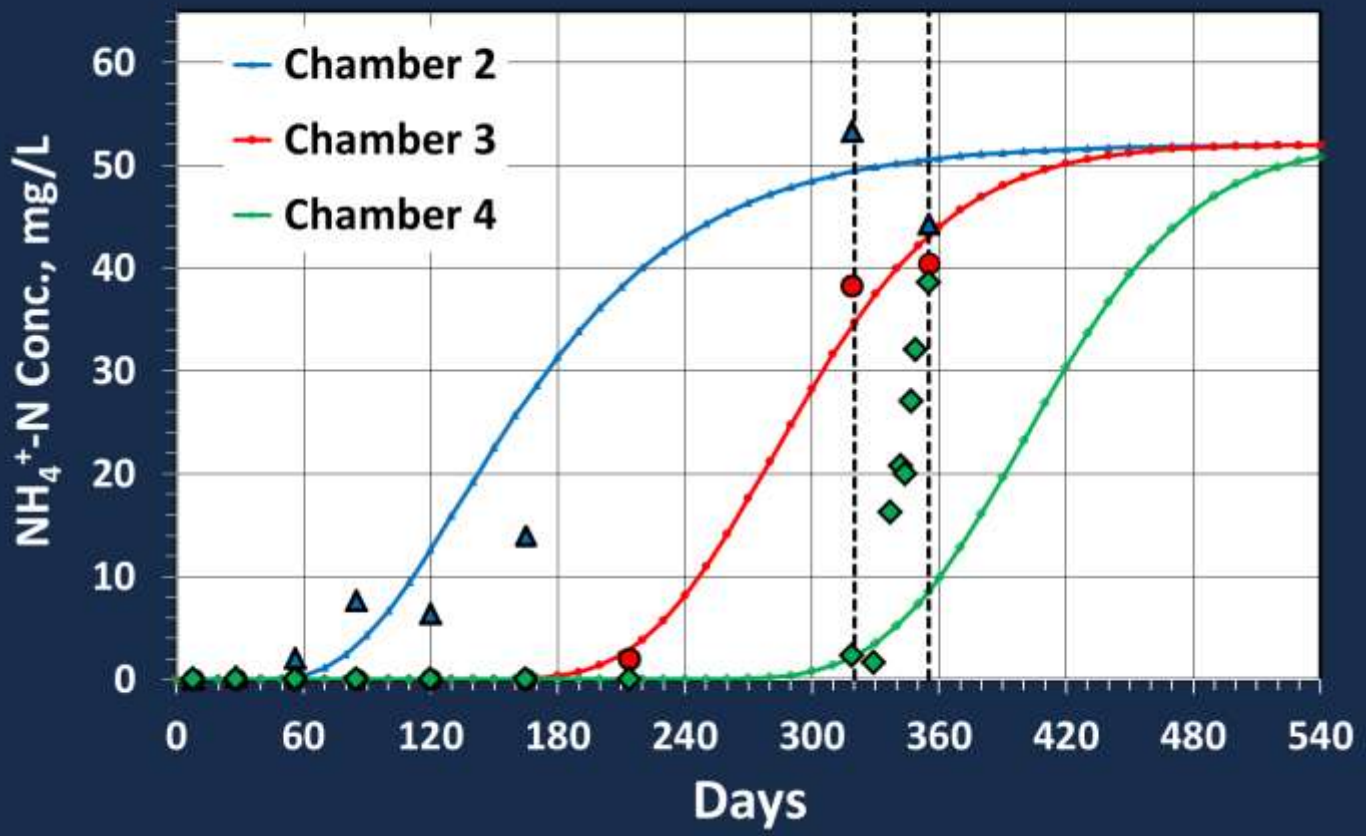
Resiliency & Forced Breakthrough





Convection/Dispersion/Adsorption

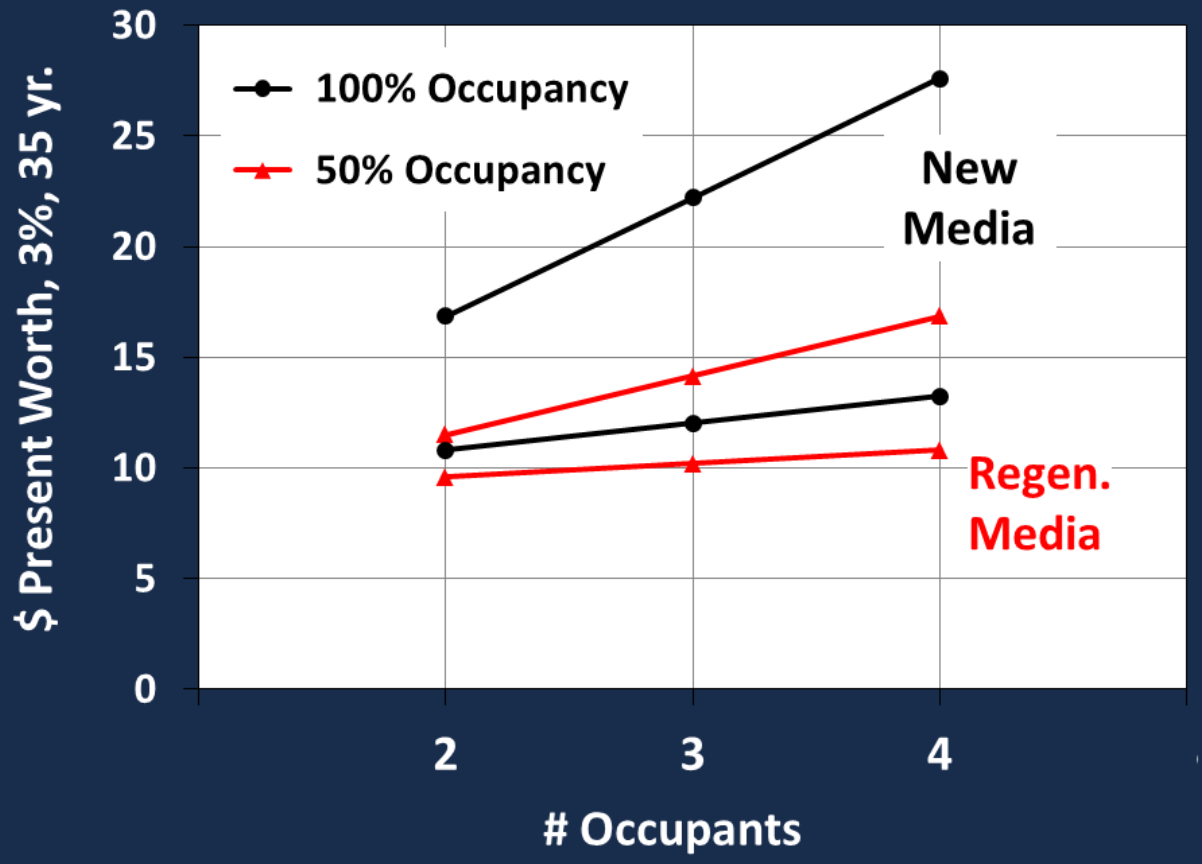
$$\frac{dC}{dt} = \frac{1}{R}\left(D\frac{d^2C}{dz^2} - v_o\frac{dC}{dz}\right)$$



NH_4^+ Capacity

	Florida	Maryland
Site Wastewater	County Park Residence and Day Lavatory	Influent to WWTP
Days Operated	662	355
Temperature Range, ^oC	23-31	7-17
Mean Influent Total Nitrogen, mg/L	44.2	56.0
NH_4^+ Capacity, mg N/g dw	11.3	13.5

Life Cycle Cost



AN-IX Summary

- Passive
- Reliable
- Low footprint
- High % nitrogen reduction
- Low temperature
- No alkalinity

AN-IX Summary (Cont.)

- Plug and play
- Easy to monitor
- East to fix
- Seasonal & on/off operation
- Scalable

Zeolite Regeneration / Nitrogen Recovery

- Chemical
- Biological
  -

Chemical Regeneration

- Alkaline regenerant
- Nitrogen transfer to capture solution
- Reuse of regenerant

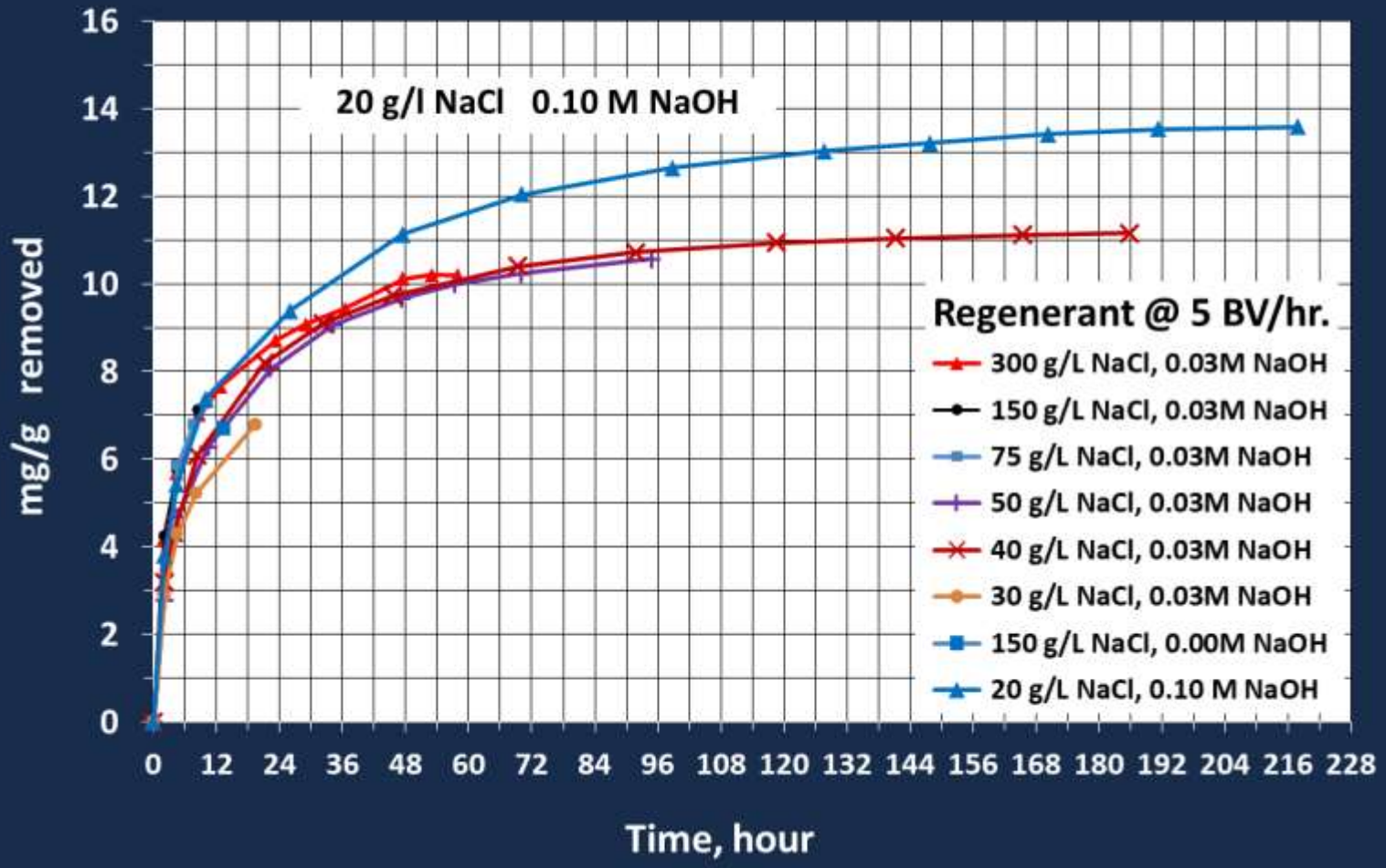
Septic Tank Effluent

NH_4^+-N, mg/L	80
pH	8.0
Alkalinity, mg/L	260
COD, mg/L	150
Conductivity, mS/cm	1.6

Anions	mg/L	Cations	mg/L
Cl^-	24	Ca^{+2}	227
SO_4^{-2}	75.6	Mg^{+2}	9.2
HCO_3^-	315	Na^+	94.2
		K^+	2.3

Alkaline/Salt Regeneration

4 x 8 Nv-Na 2.4-4.8mm



Repeating Load & Regen Cycles

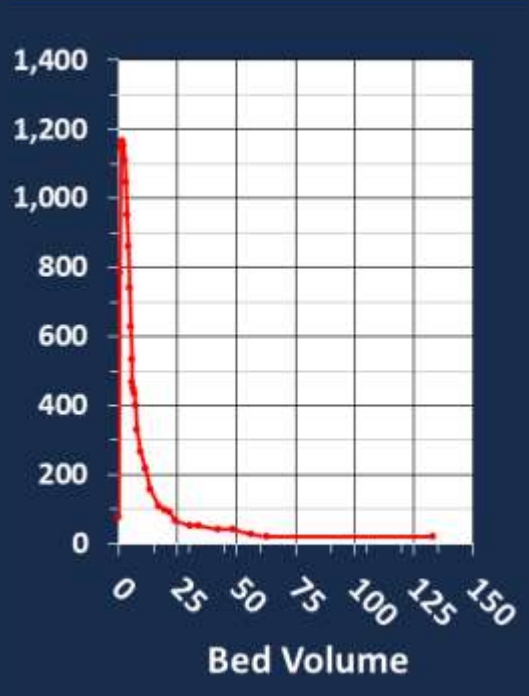
14 x 40 Nv-Na

Loading

2 - 3 yr.

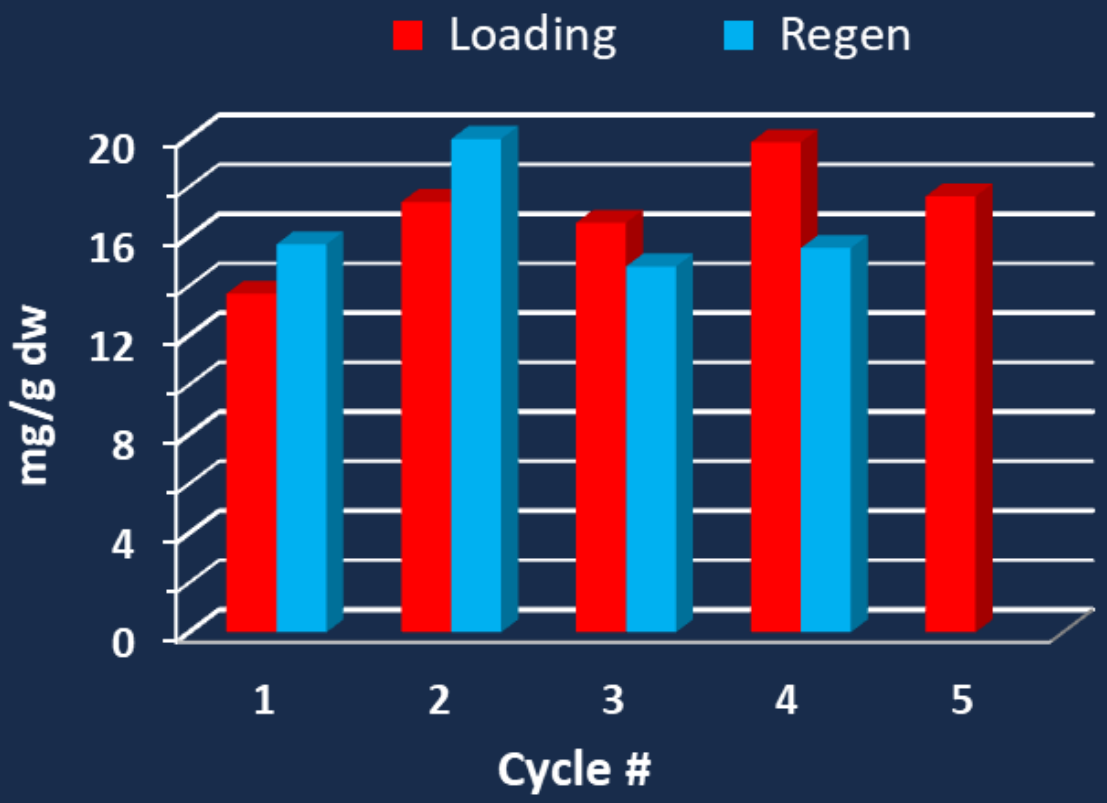
Regeneration

1 day



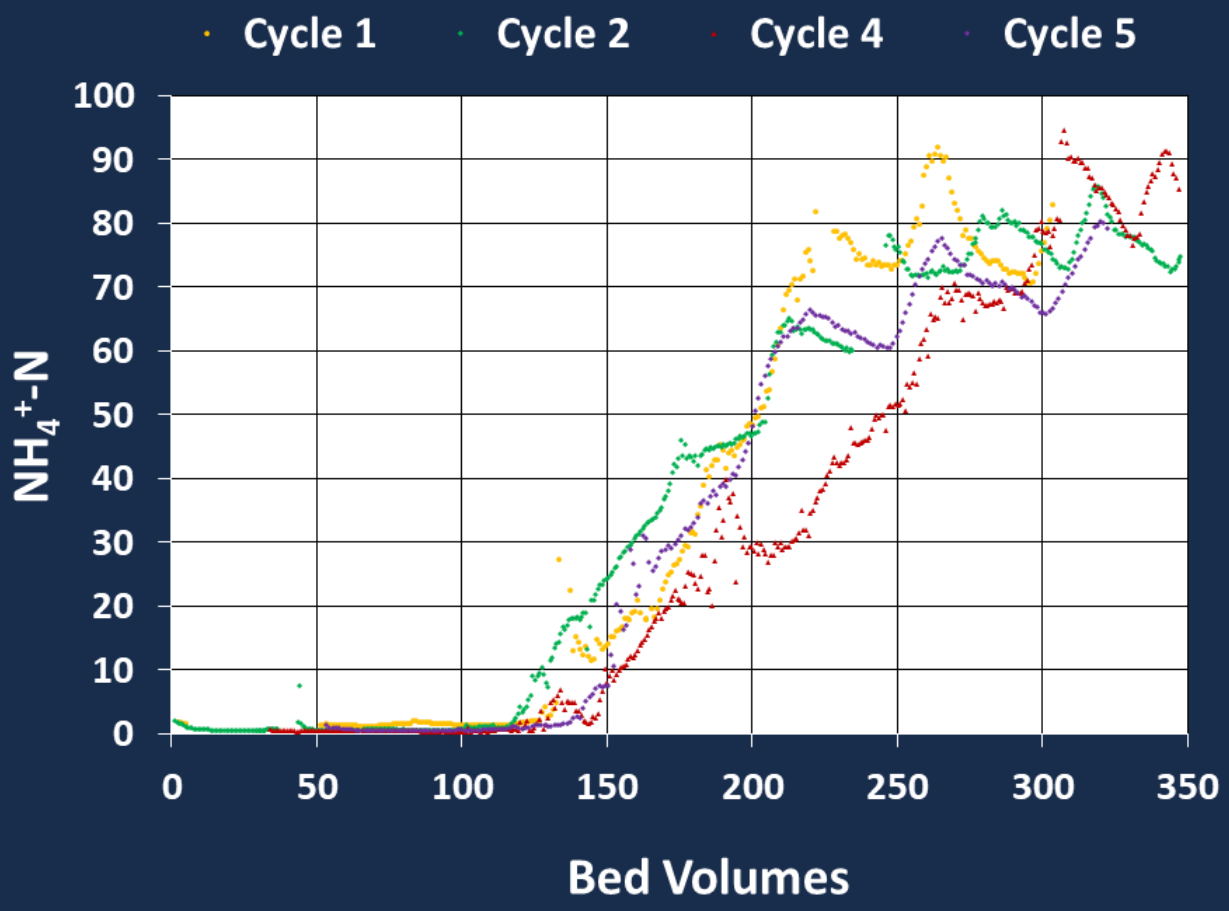
Load & Regen Cycles

14 x 40 Nv-Na



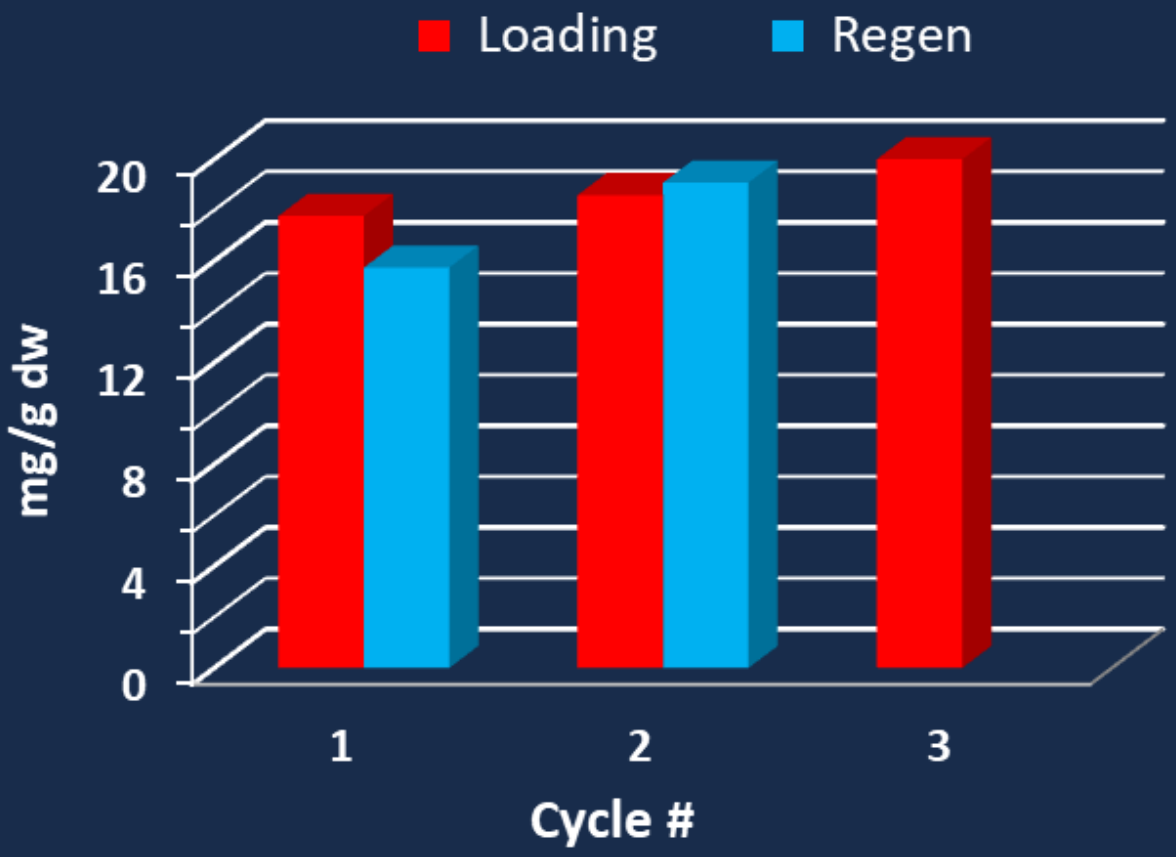
Breakthrough Curves

14 x 40 Nv-Na



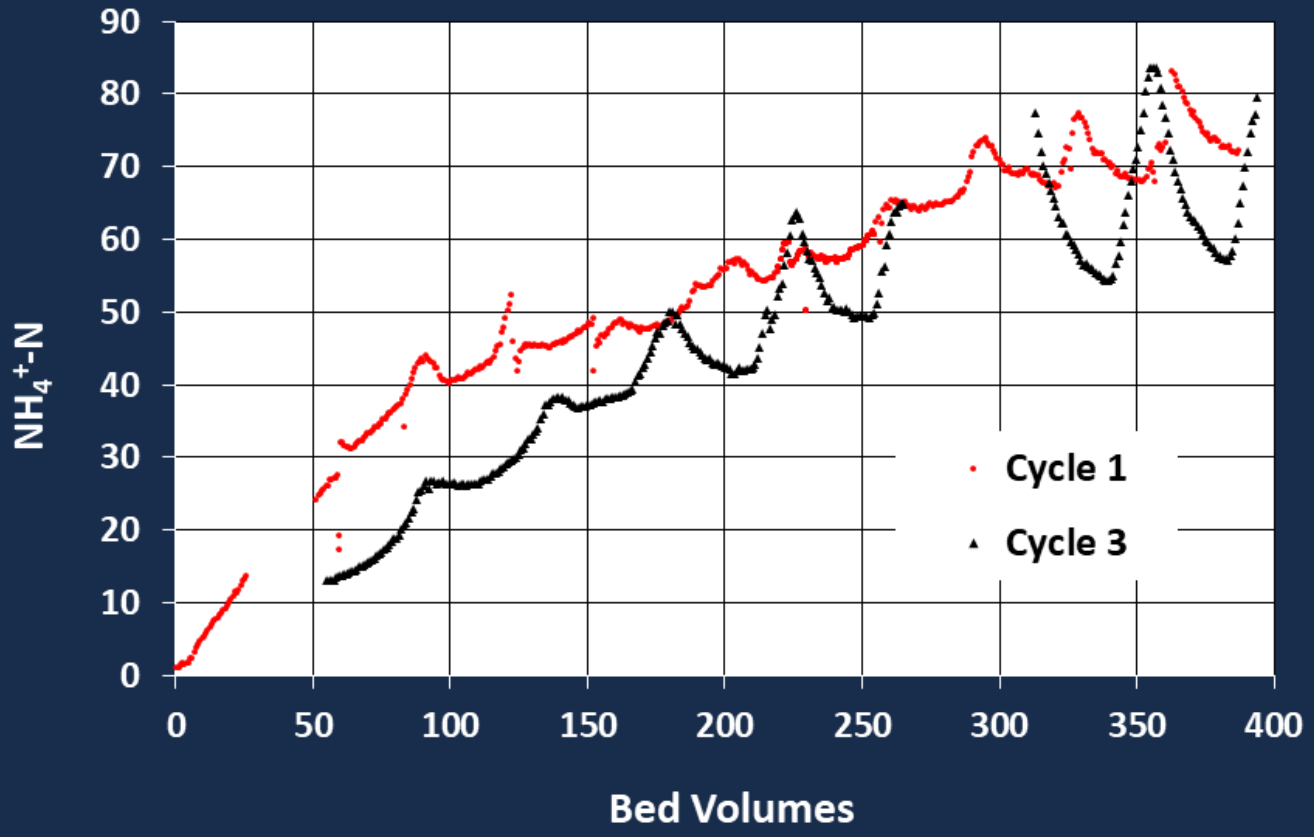
Load & Regen Cycles

4 x 8 Nv-Na



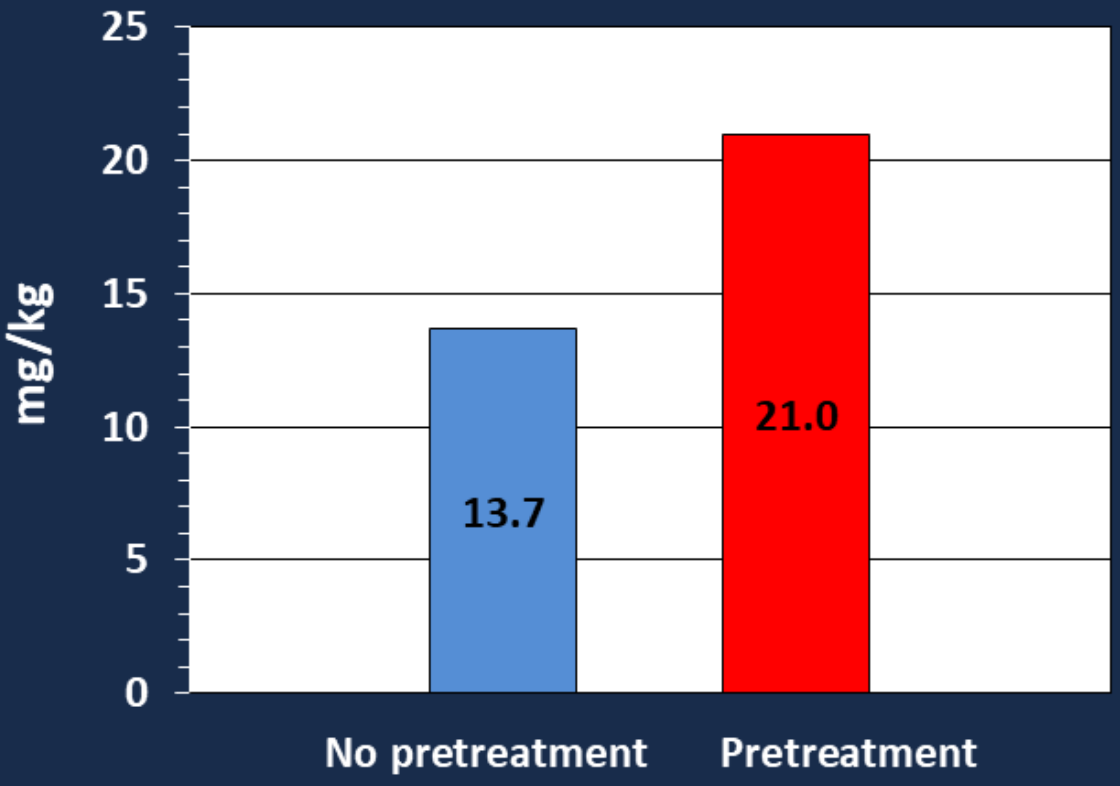
Breakthrough Curves

4 x 8 Nv-Na



Pretreat Nv-Na at Initial Startup

20 hr. @ 20 g/l NaCl, 0.1M NaOH

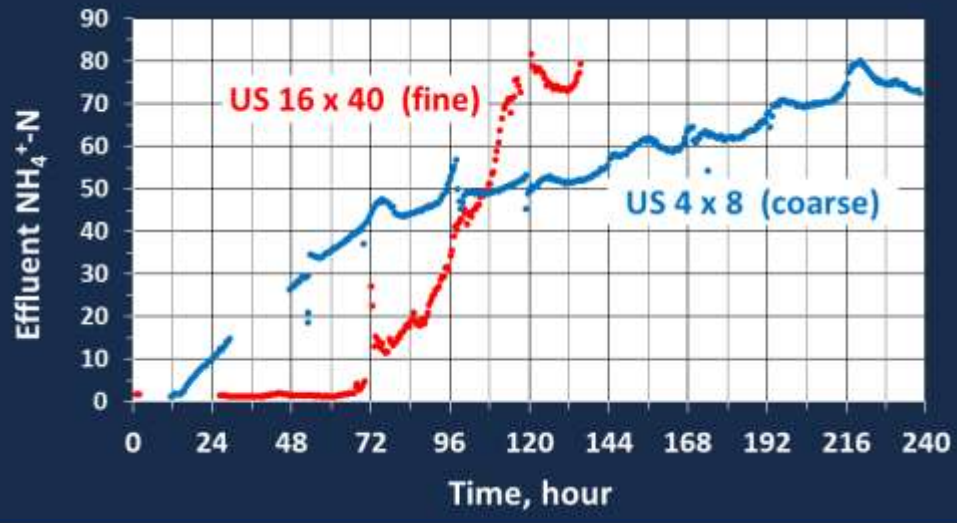


Significant capacity increase in first cycle

Effect of Particle Size

Loading

- 1.7 BV/hr.

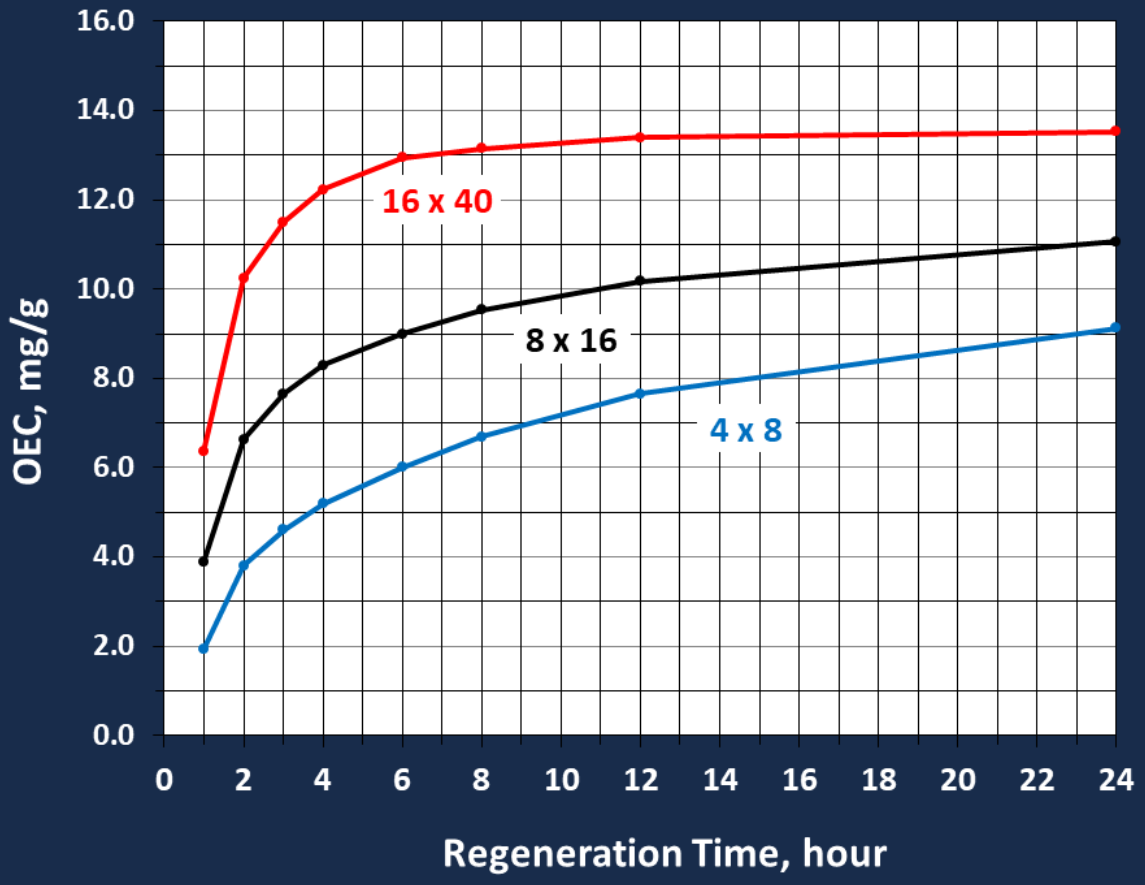


Regeneration

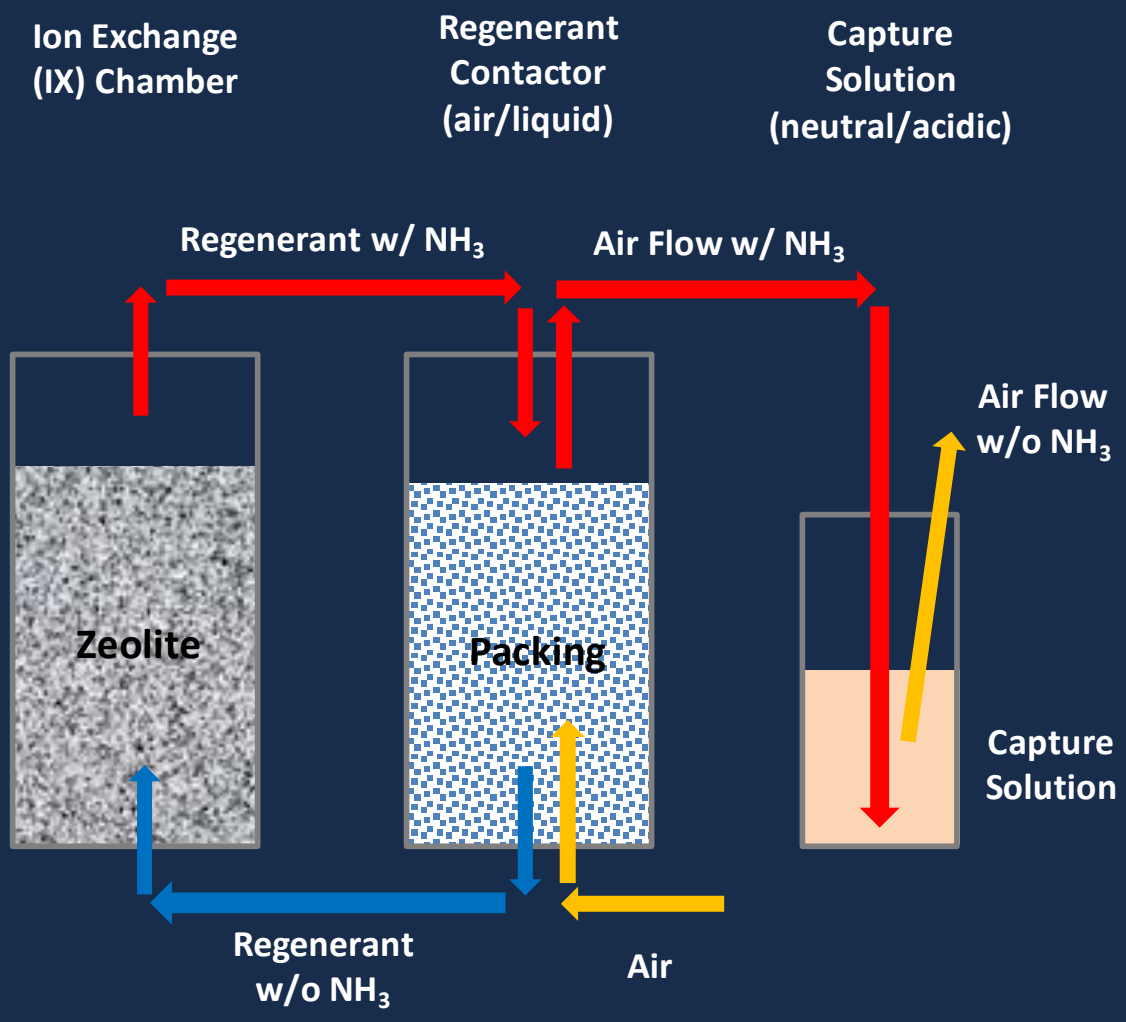
- 5 BV/hr.

Operational Exchange Capacity (OEC)

Shell Progressive Model (SPM)



Nitrogen Capture



Design fertilizer

Capture solution	Nitrogen compound
H_2SO_4	$(NH_4)_2SO_4$
HNO_3	NH_4NO_3
Na_2CO_3	$(NH_4)_2CO_3$
$NaHCO_3$	NH_4HCO_3
HCl	NH_4Cl

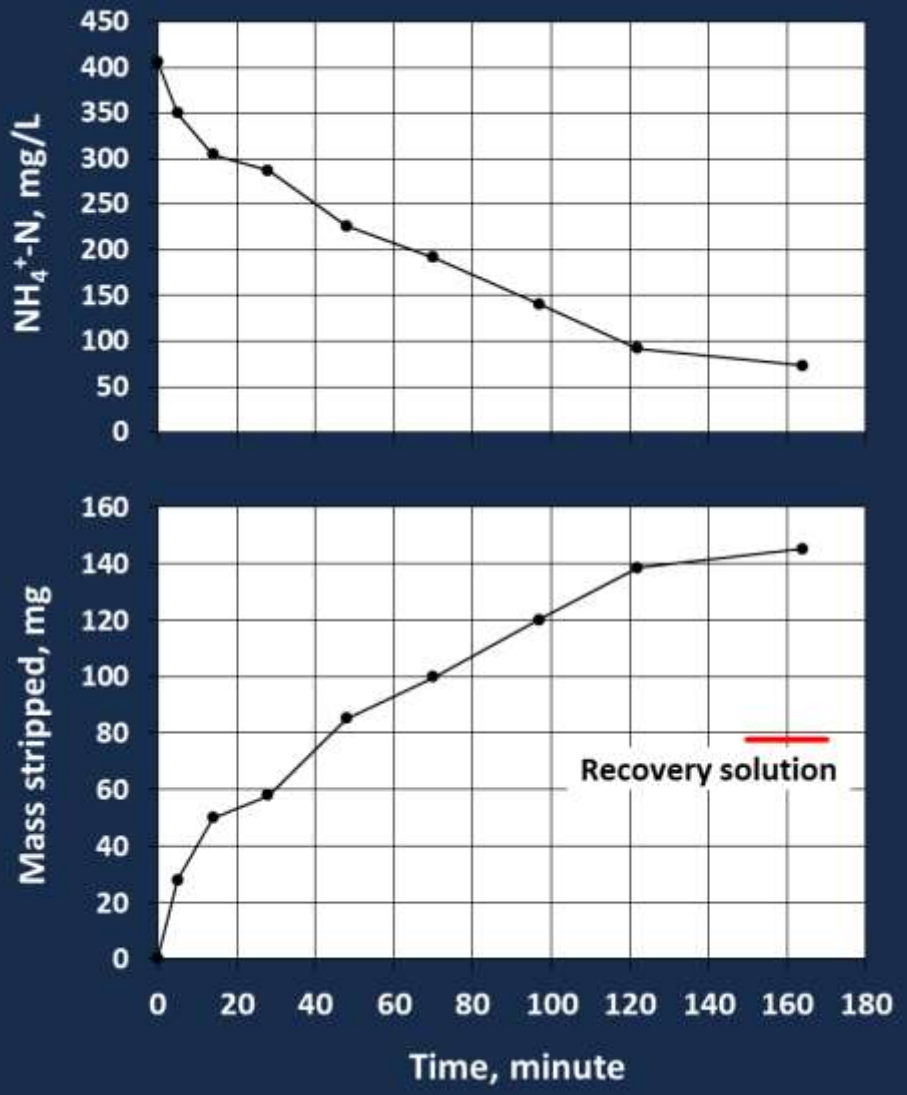
Strip & Recover

Regenerant

- 20 g/L NaCl
- O.10M NaOH

Recovery

- 3N H_2SO_4

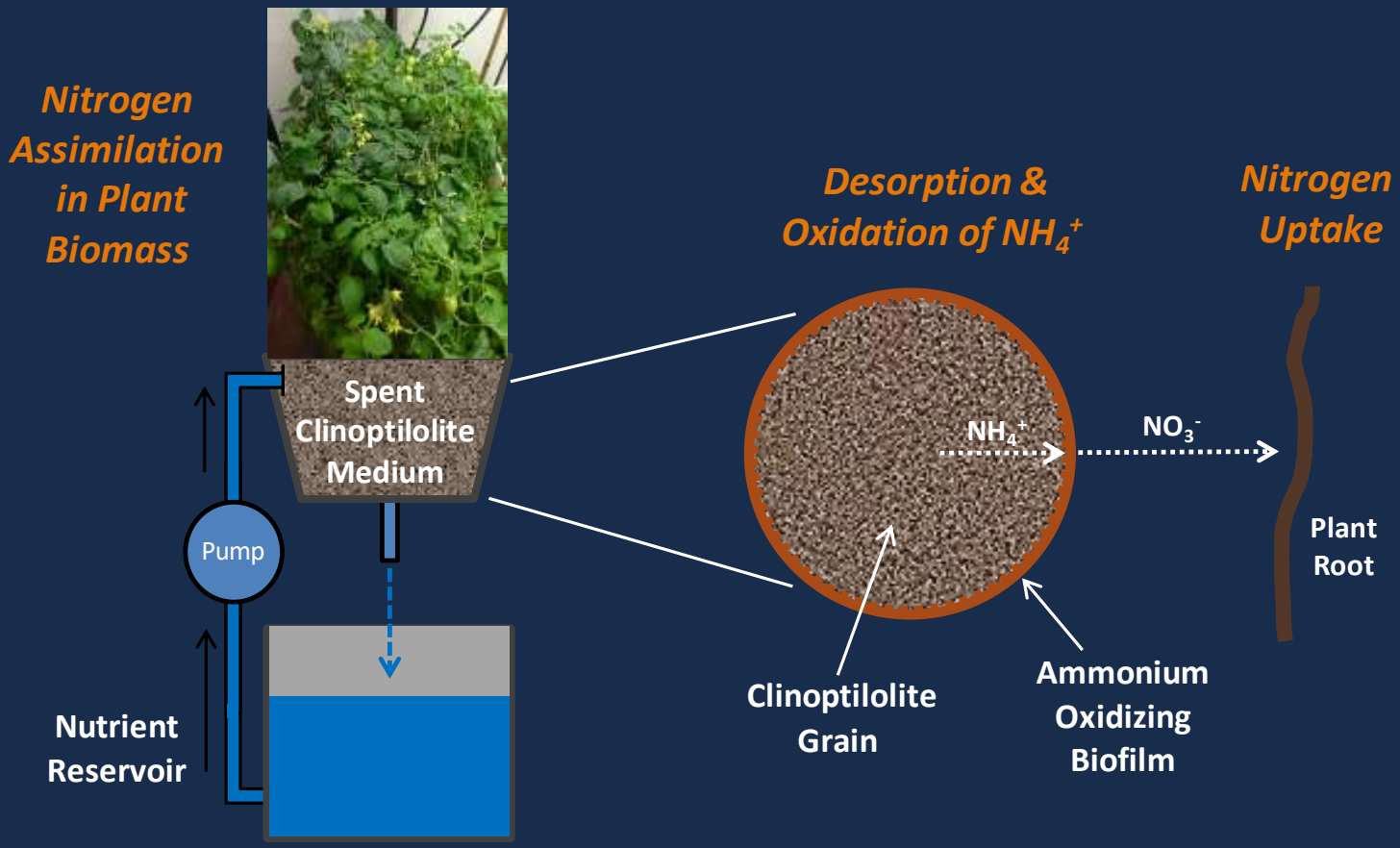


Biological Regeneration

- Bioextraction of NH_4^+
- Plant growth on NH_4^+/NO_3^-
- Incorporate N into plant protein
- Suitable for value added plants

Microbial Extraction / Plant Uptake

Flood & Drain Hydroponics

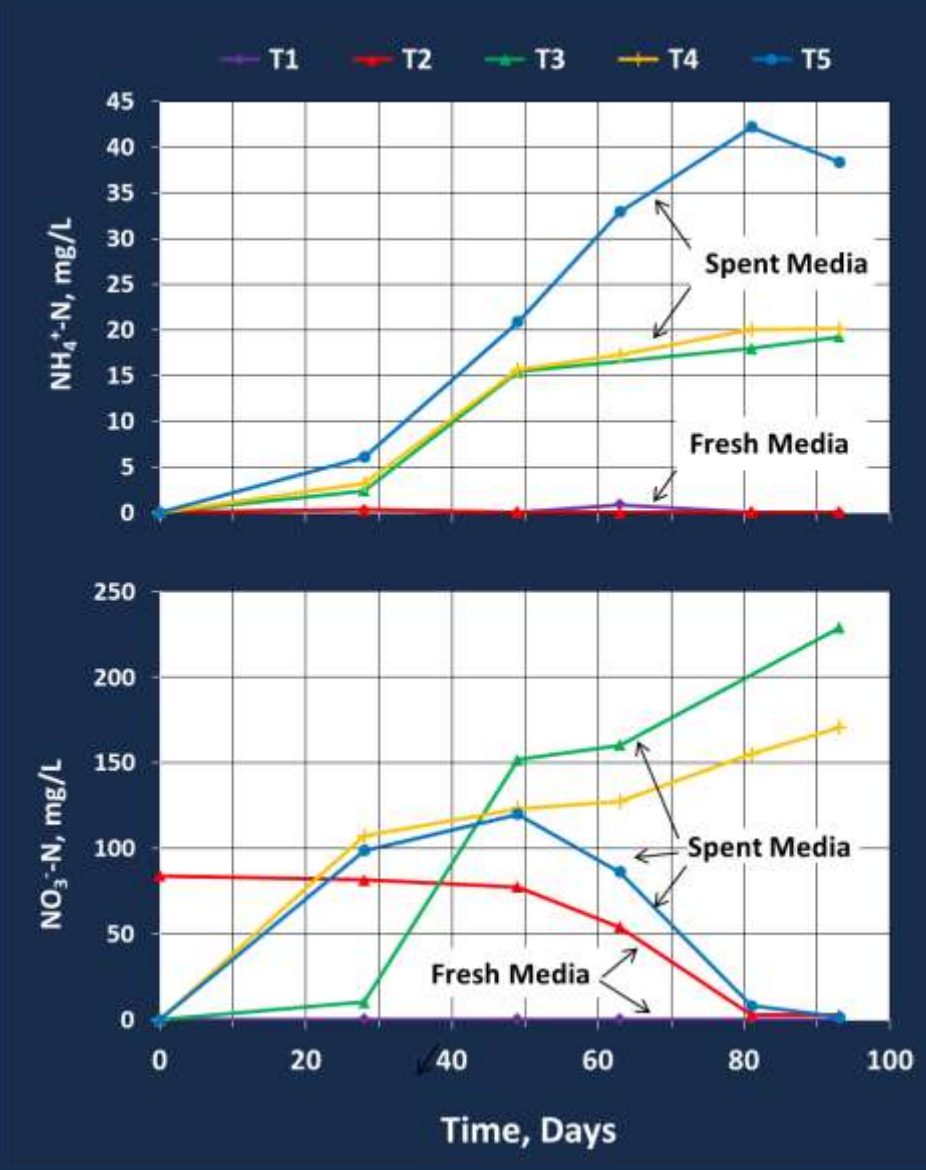


6 Parallel Treatments

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

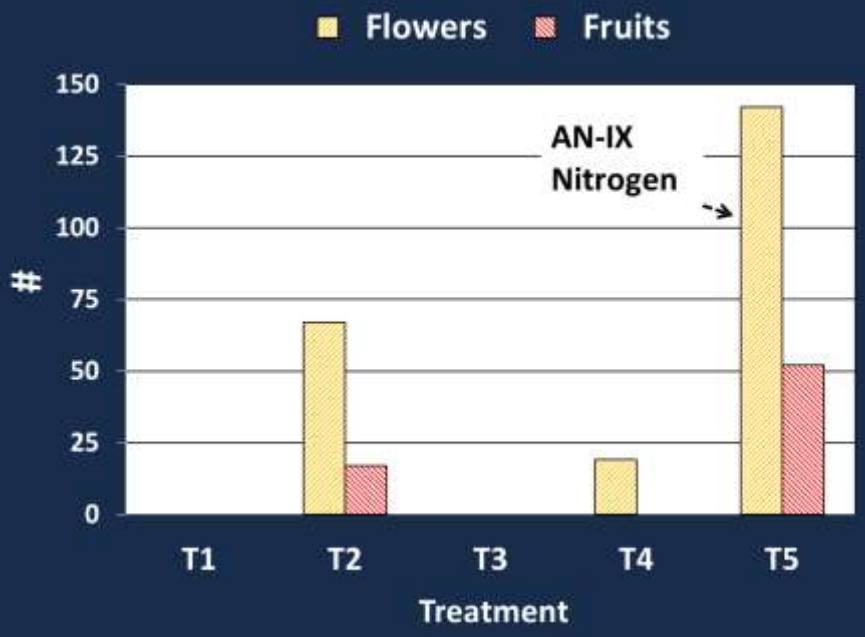
*Waste and Biomass Valorization, 2017

Nitrogen Release Dynamics



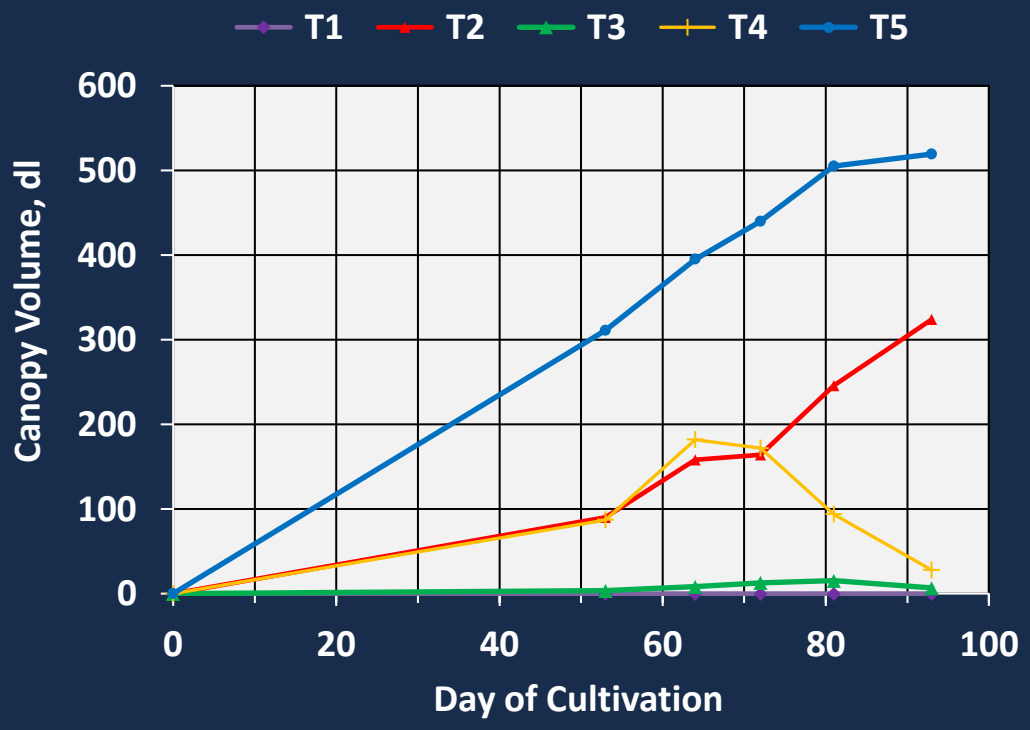
Fruits & Flowers

Growth on recovered wastewater nitrogen



Solanum lycopersicum Cultivation*

Spent clinoptilolite provides all nitrogen for growth



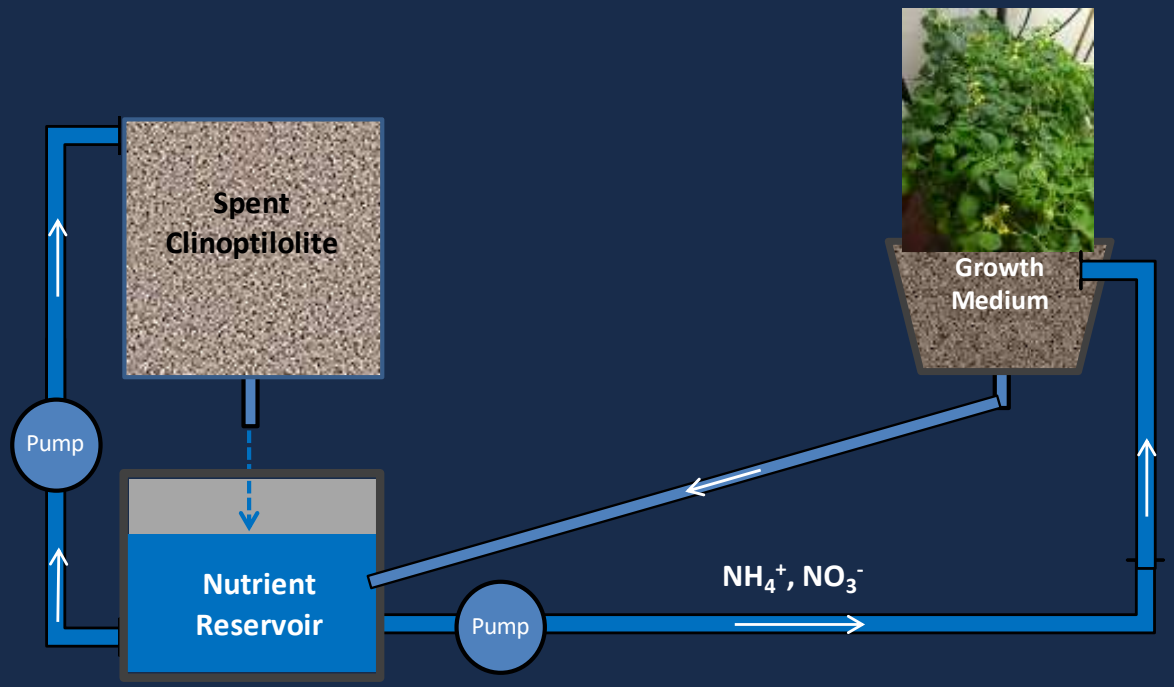
250 mmol/m^2-sec Photosynthetic Photon Flux
@ 12 hour on/off cycle

*Waste and Biomass Valorization, 2017

System for Zeolite Bioregen. & Reuse

Microbial Extraction

Nitrogen Assimilation



AN/IX/Regen

- Regenerate and reuse zeolite
- Recover nitrogen
- Chemical: design fertilizer & regenerant recycle
- Biological: plant proteins

Dr. Daniel P. Smith, P.E., BCEE
AET Tech LLC
Daniel.Smith.AET@outlook.com
(813) 716-2262 (617) 657-0753