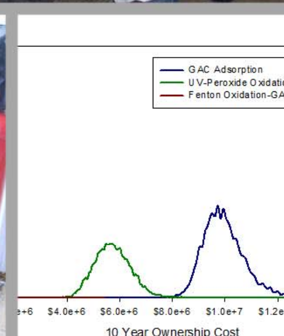
Cometabolic Degradation of Insensitive Munitions Constituents During Nitrification



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Define insensitive munitions

Define biogeochemical transformations of interest

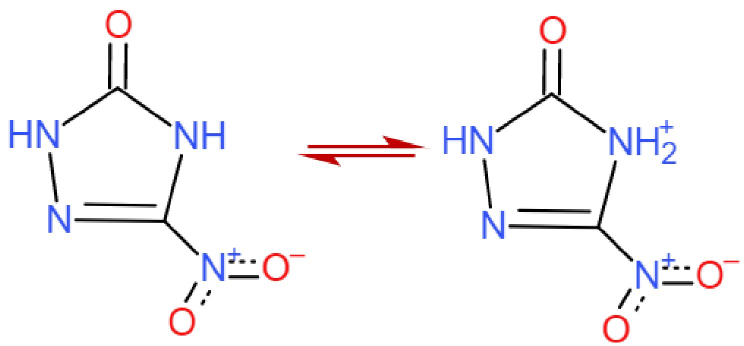
Describe experiments challenging a nitrifying enrichment with insensitive munitions constituents

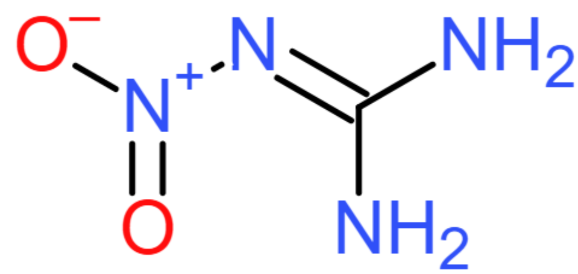
Insensitive Munitions

- Required for increased soldier safety and prevention of material losses (DoDI 5000.02, 10 USC 2389)
- Articles containing insensitive formulations are entering Army inventory

Camp Doha (1991) – 51 Soldiers injured and 102 vehicles damaged or destroyed

Insensitive Munitions





Nitrotriazolone (NTO)
Water solubility of 12 g/L
Wastewater pH of 3
Much less toxic than older explosives, but much more mobile in the environment.

Nitroguanidine
Water solubility of 3 g/L
Stable in many wastewater treatment systems
More mobile than older explosives in the environment, and phototransforms to toxic byproducts.

Insensitive Munitions

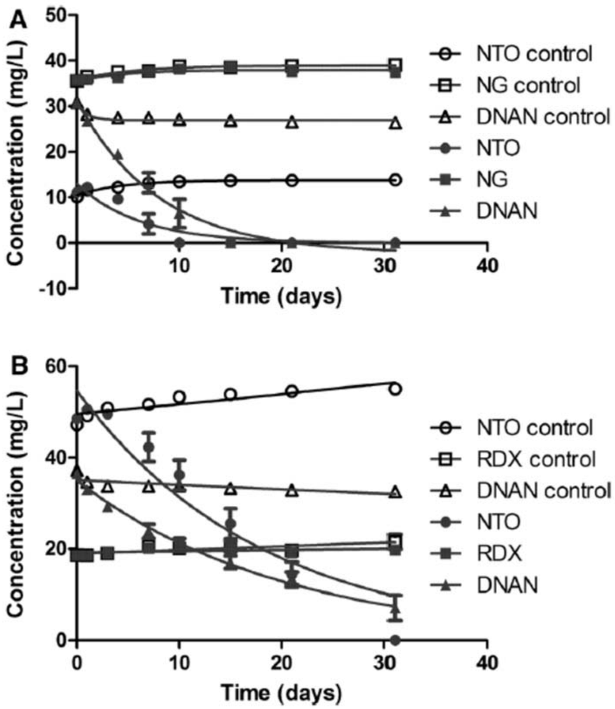


Fig. 1 Anaerobic degradation of IMX101 (**a**) and IMX104 (**b**) insensitive munition formulations in Camp Shelby (CS) surface soil microcosms incubated over a 30-day period. Standard deviations of triplicate microcosms are shown. Controls refer to soils that have been heat inactivated by autoclaving

Indest, et al. *J Indust Microbiol Biotechnol,* (2017) 44:987-995

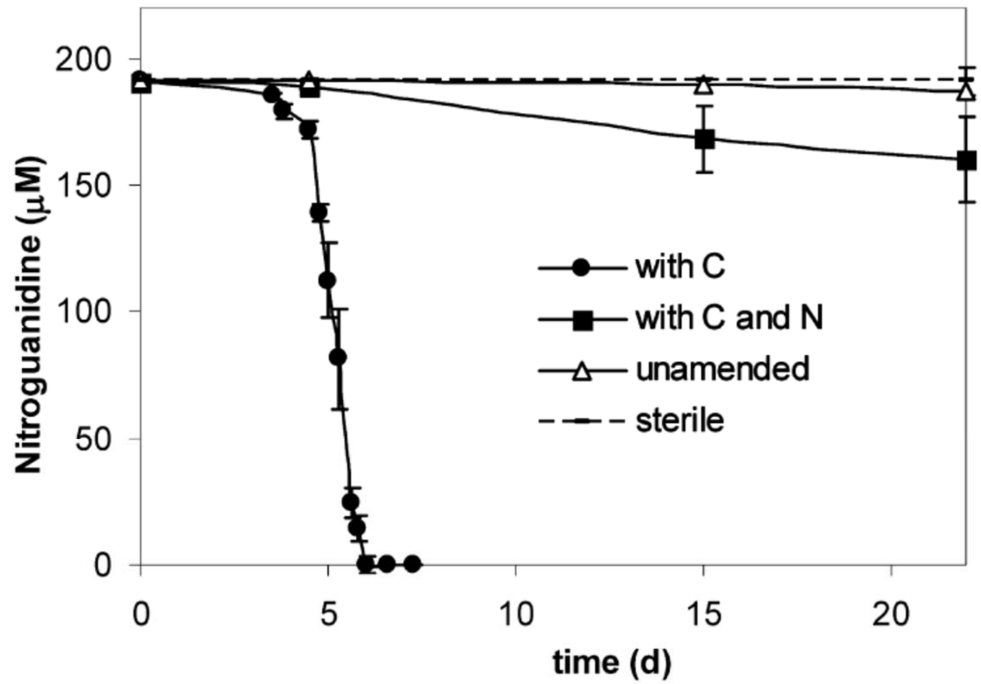
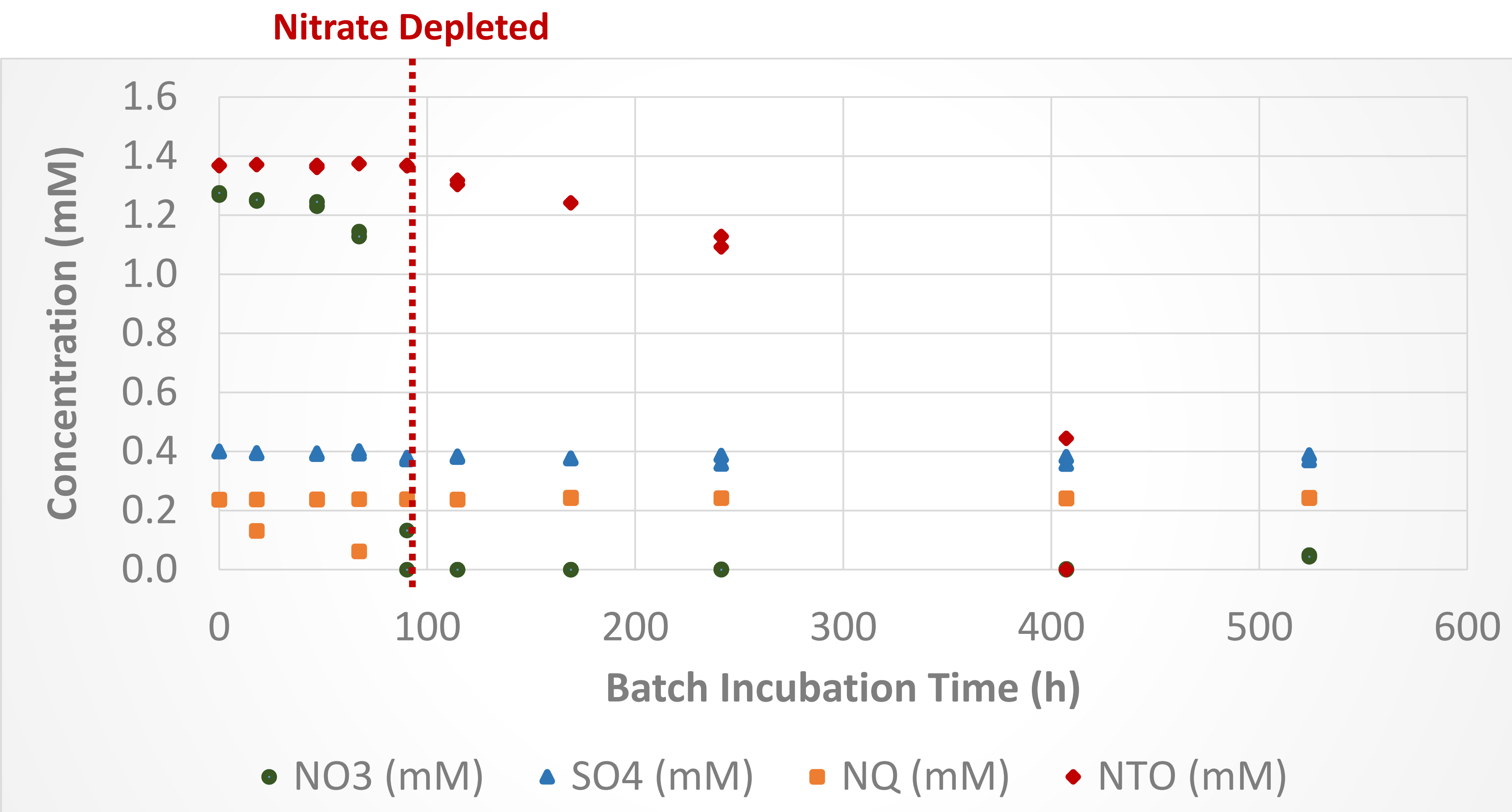


Figure 1. Biotransformation of NQ in aerobic soil microcosms. C, carbon sources (glucose and succinate); N, nitrogen source (NH_4Cl). Error bars represent the standard deviation of the mean from triplicate experiments.

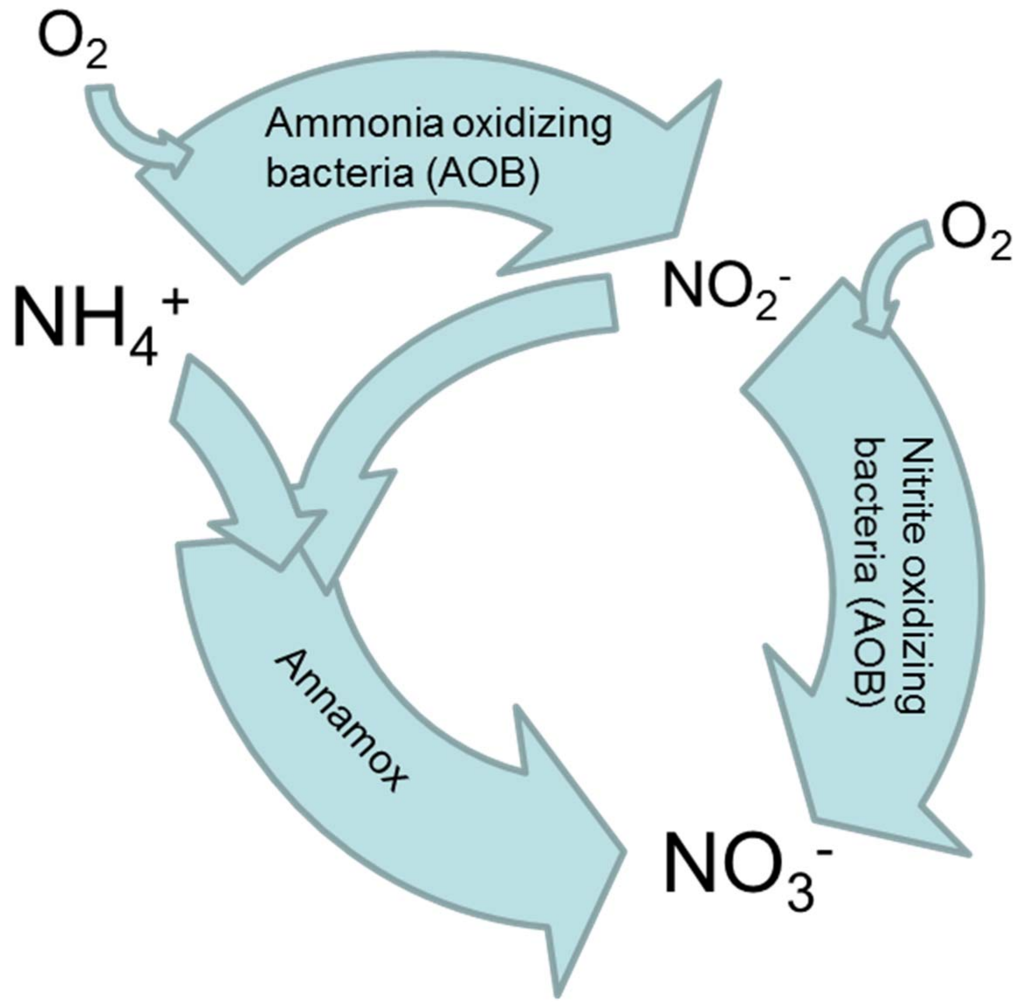
Perreault, et al. *Environ Sci Technol,* (2012) 46:6035-6040

Anoxic Degradation



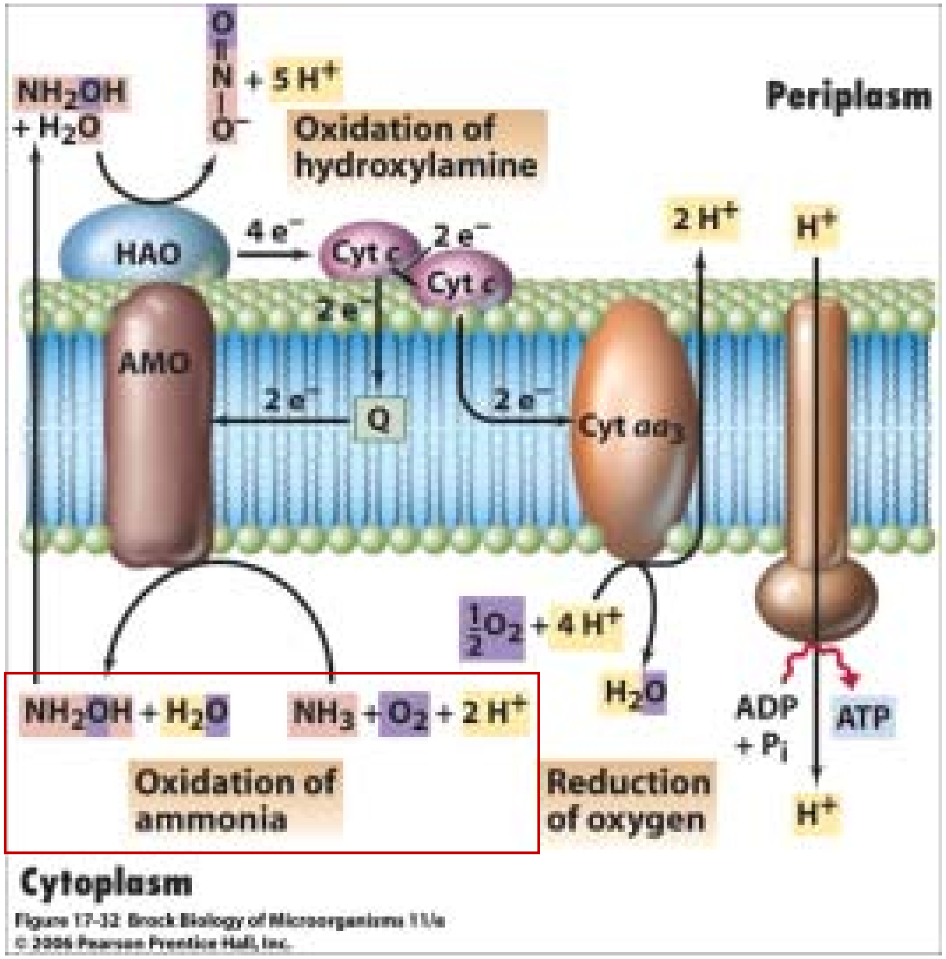
Nitrification

The aerobic process that oxidizes ammonium to nitrate via nitrite. Generally accomplished by two types of bacteria, except in special circumstances.



Nitrification

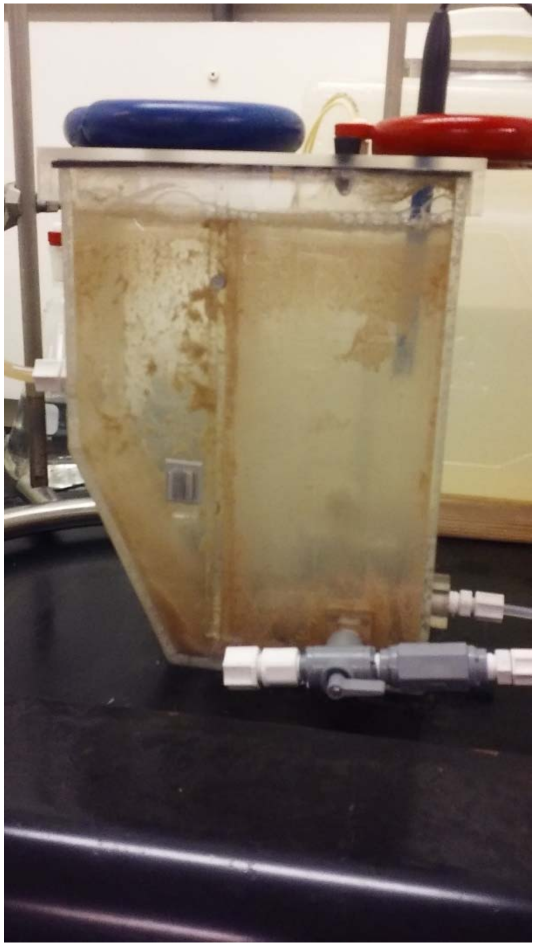
- Ammonium Monooxygenase (AMO)
  - $NH_3 \rightarrow NH_2OH$
- Also capable of oxidizing
  - Methane
  - Bromoethane
  - Ethylene
  - Propylene
  - Cyclohexane
  - Benzene
  - Phenol



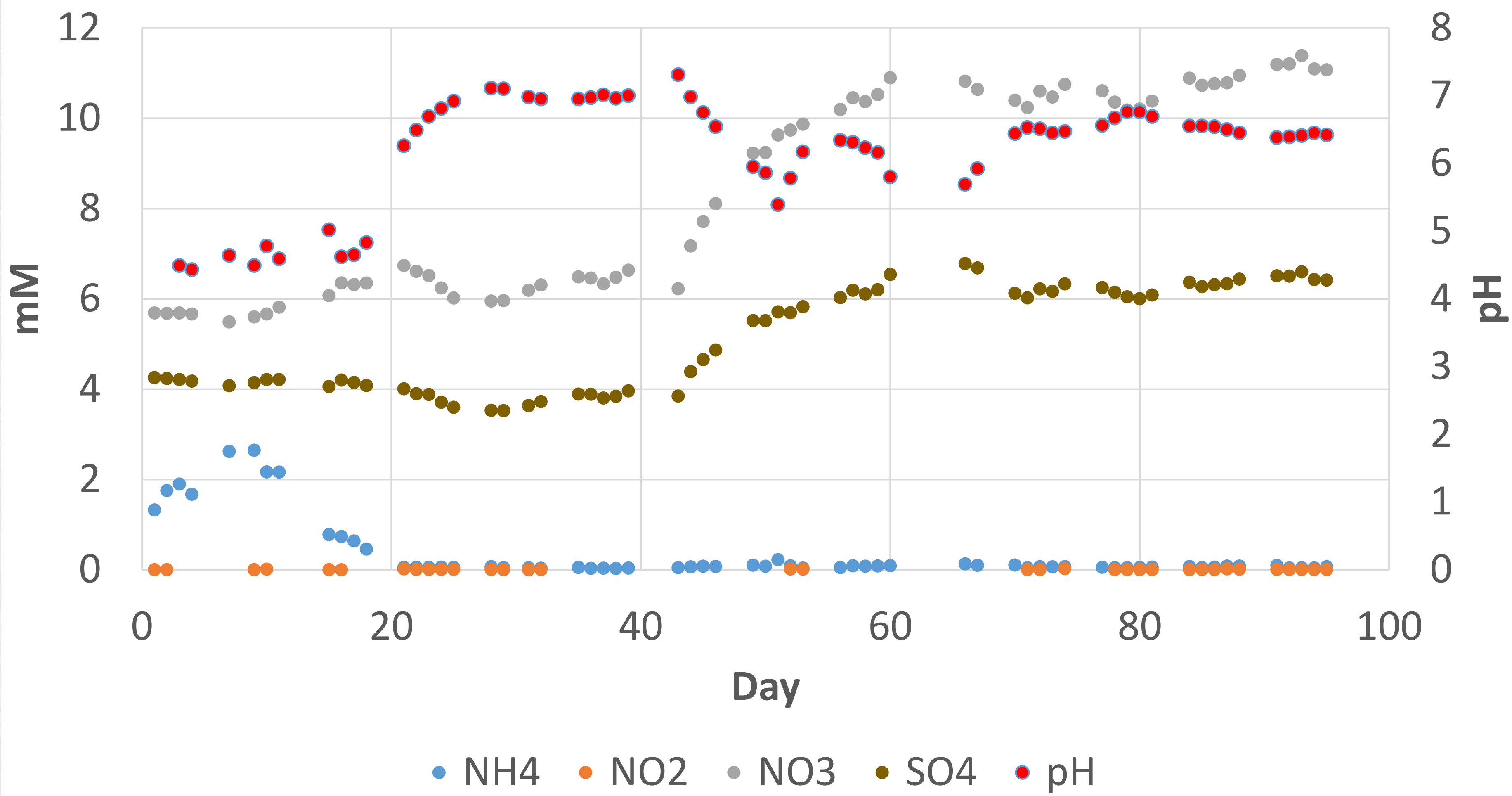
(Prosser, The Ecology of Nitrifying Bacteria, 2007)

Establishing a Nitrifying Culture

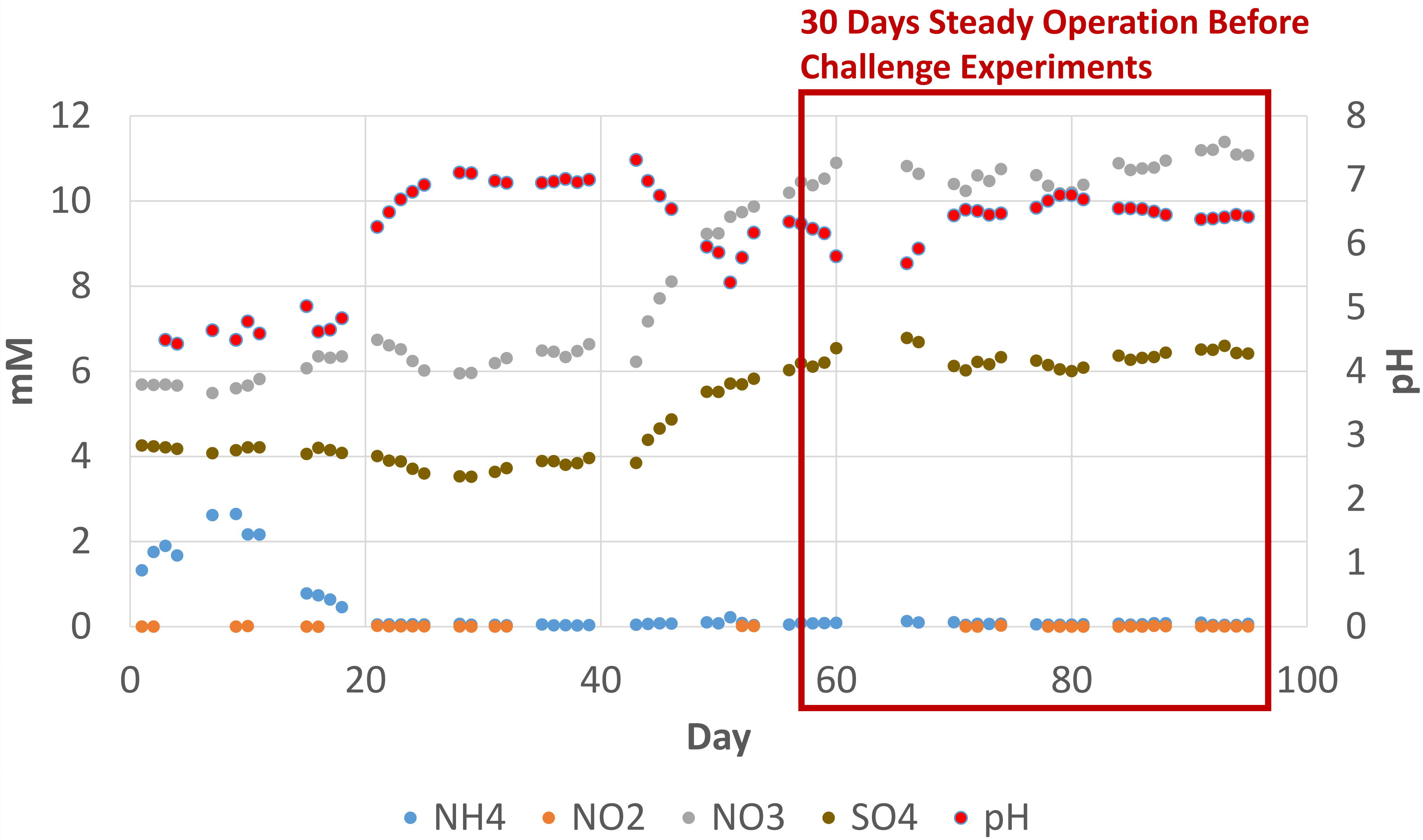
Reactor Setup	5-L Divided Reactor with mixed aeration basin and settling basin
Flow Rates	1-mL/min minimal media 0.1-mL/min 2-g/L NH_4^+
Steady State Biomass	26.6-mg VSS/L
Activity	8-g N/g VSS/d



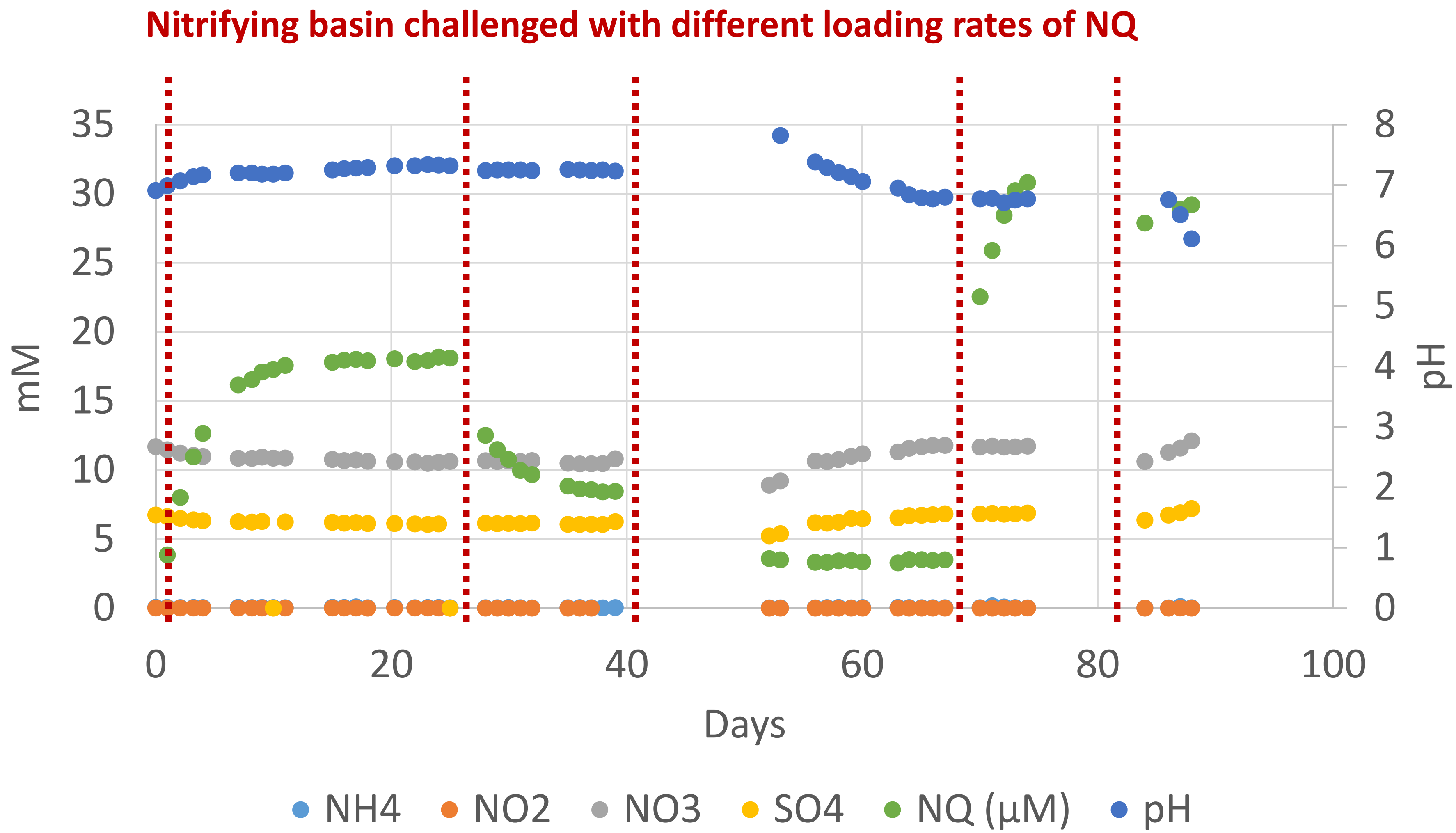
Establishing a Nitrifying Culture



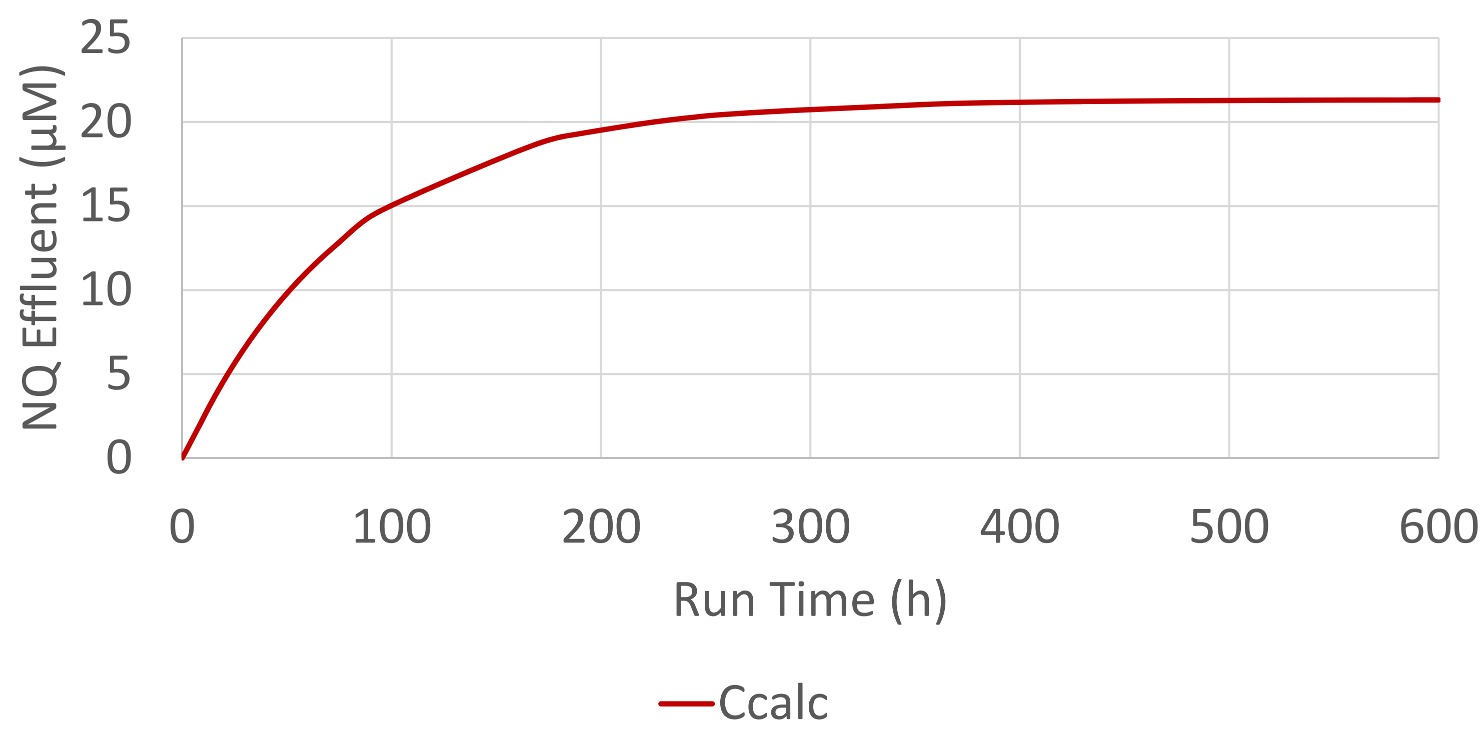
Establishing a Nitrifying Culture



Challenging Nitrifiers with IM

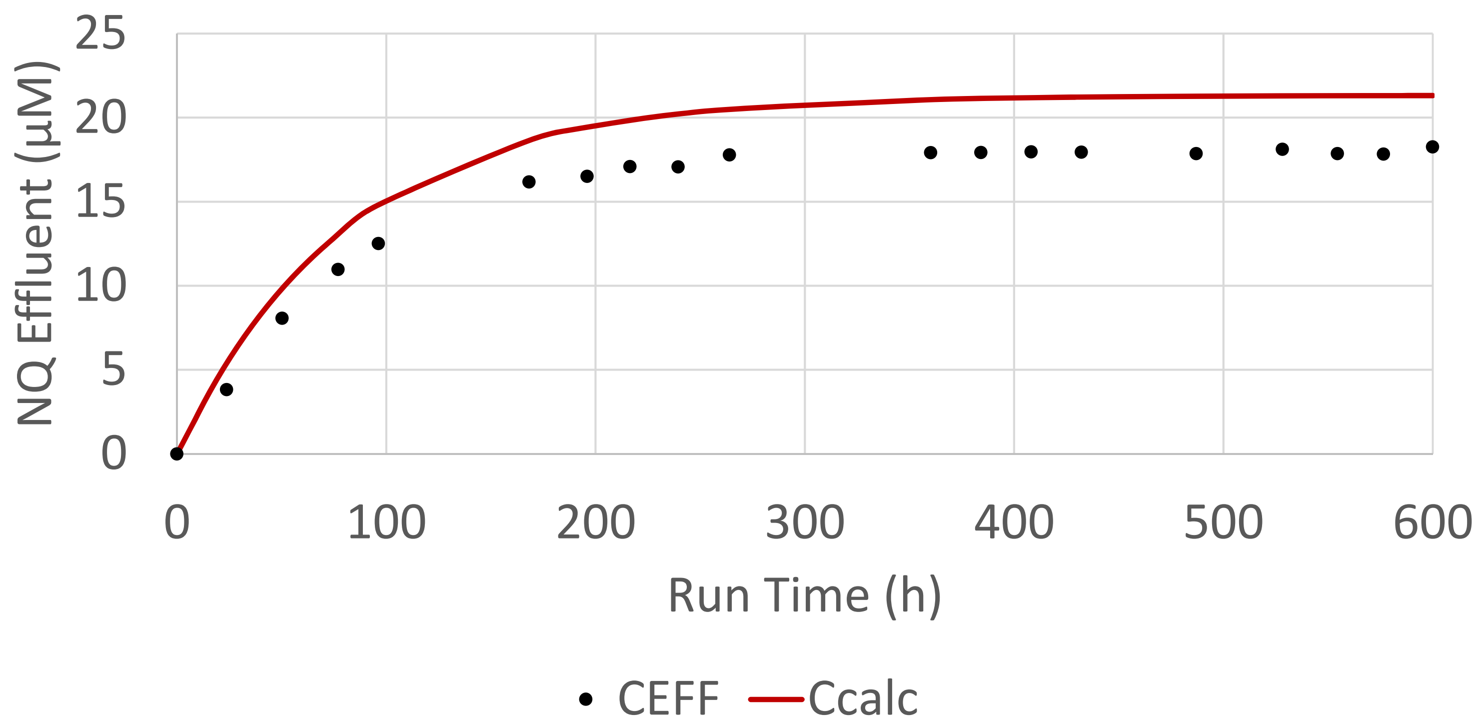


Challenging Nitrifiers with Nitroguanidine



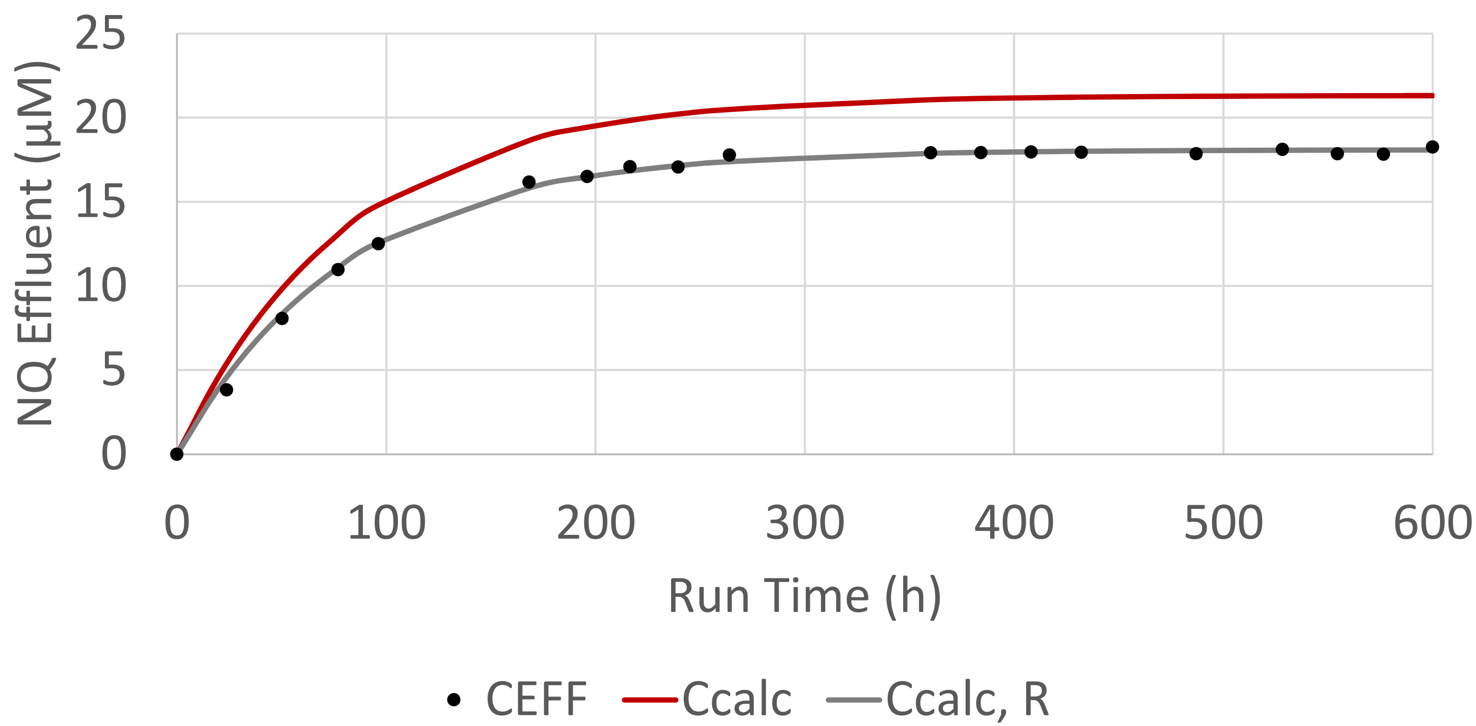
Steady State Mixing Model with No Reaction

Challenging Nitrifiers with Nitroguanidine



Steady State Mixing Model with Actual Concentration Data

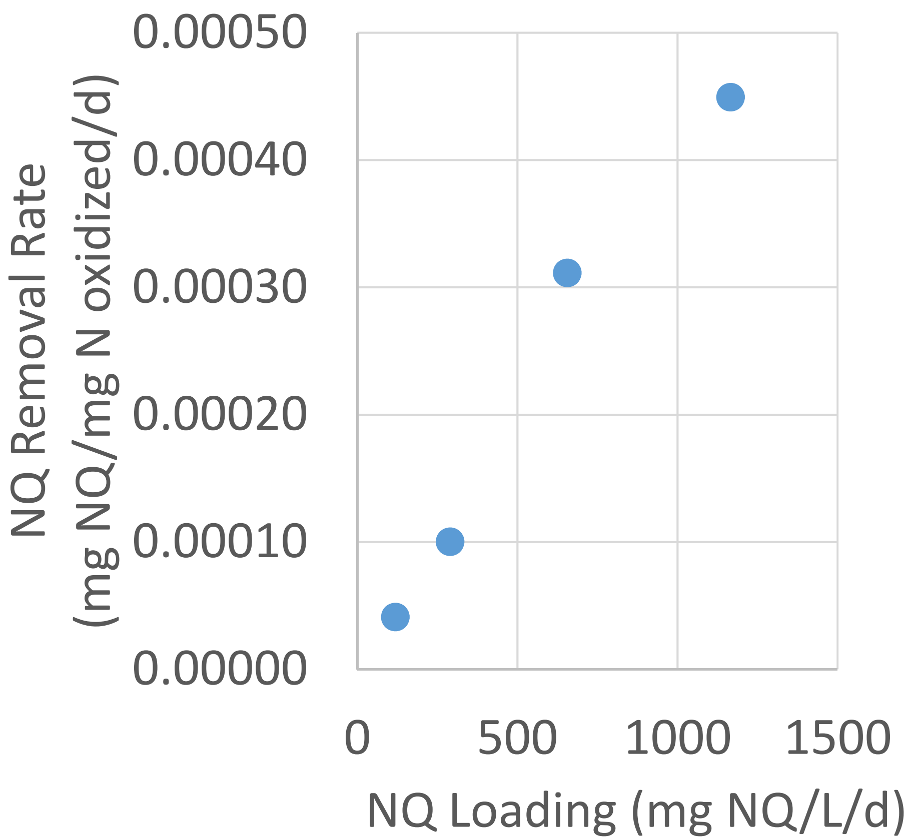
Challenging Nitrifiers with Nitroguanidine



Steady State Mixing Model with Actual Concentration Data

Root mean square of error (RMSE): 1.5 µM

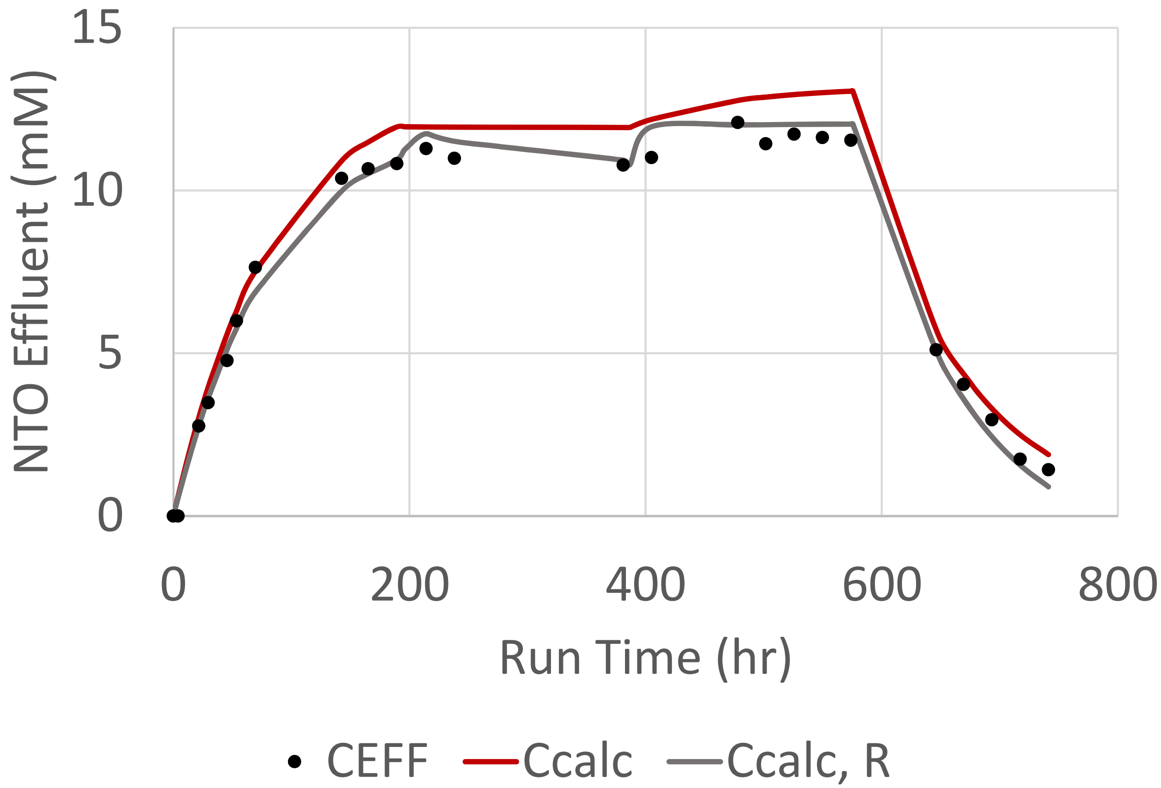
Challenging Nitrifiers with Nitroguanidine



NQ Loading Rate (mg/L/d)	NQ Removal Rate (mg/L/d)	% Removal with 81-h Residence Time
119	13.1	11%
290	32.0	11%
656	99.4	15%
1,166	143.4	12%

Root mean square of error (RMSE):
1.5 µM

Challenging Nitrifiers with NTO



Root mean square of error (RMSE):

0.43 µM

Potential Impact

- Net nitrification rates vary widely in surface soils across geographic and time scales

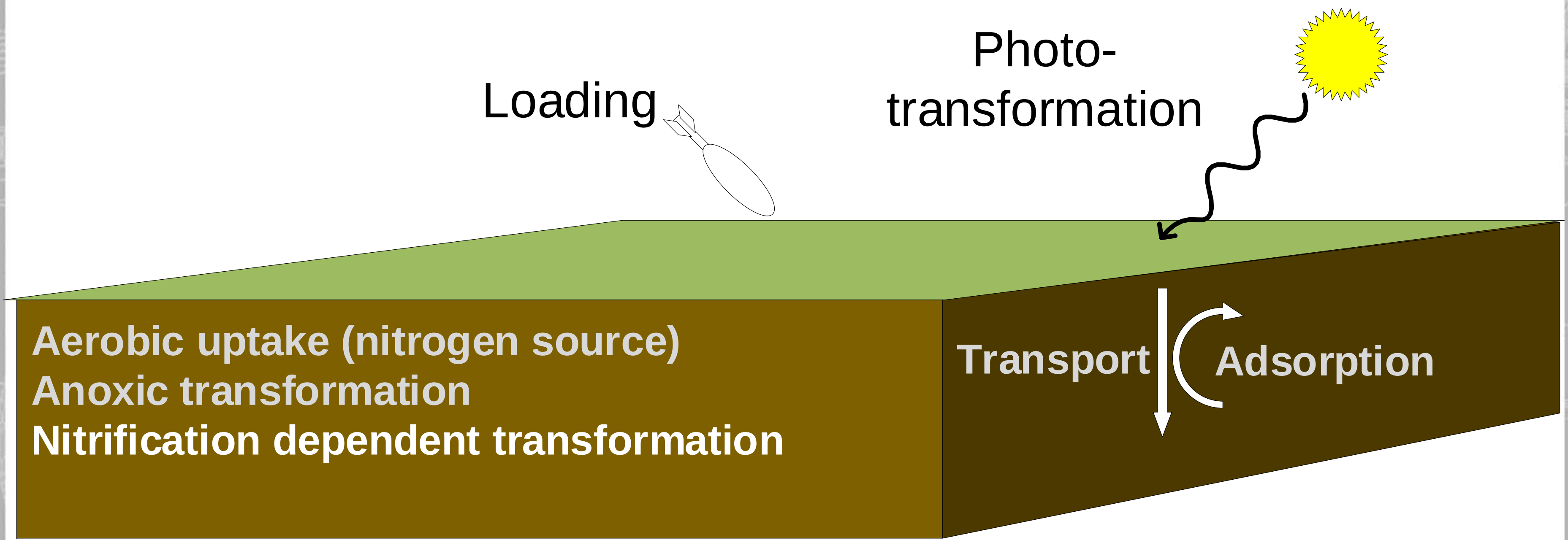
  - 2004 example measurement: 0.00 – 1.20 kg N/ha/d (Cardoso, et al., *R. Bras. Ci. Solo* (2011) 35:1651-1660)

  - Current experiments performed with net nitrification rate of 0.2 g/d

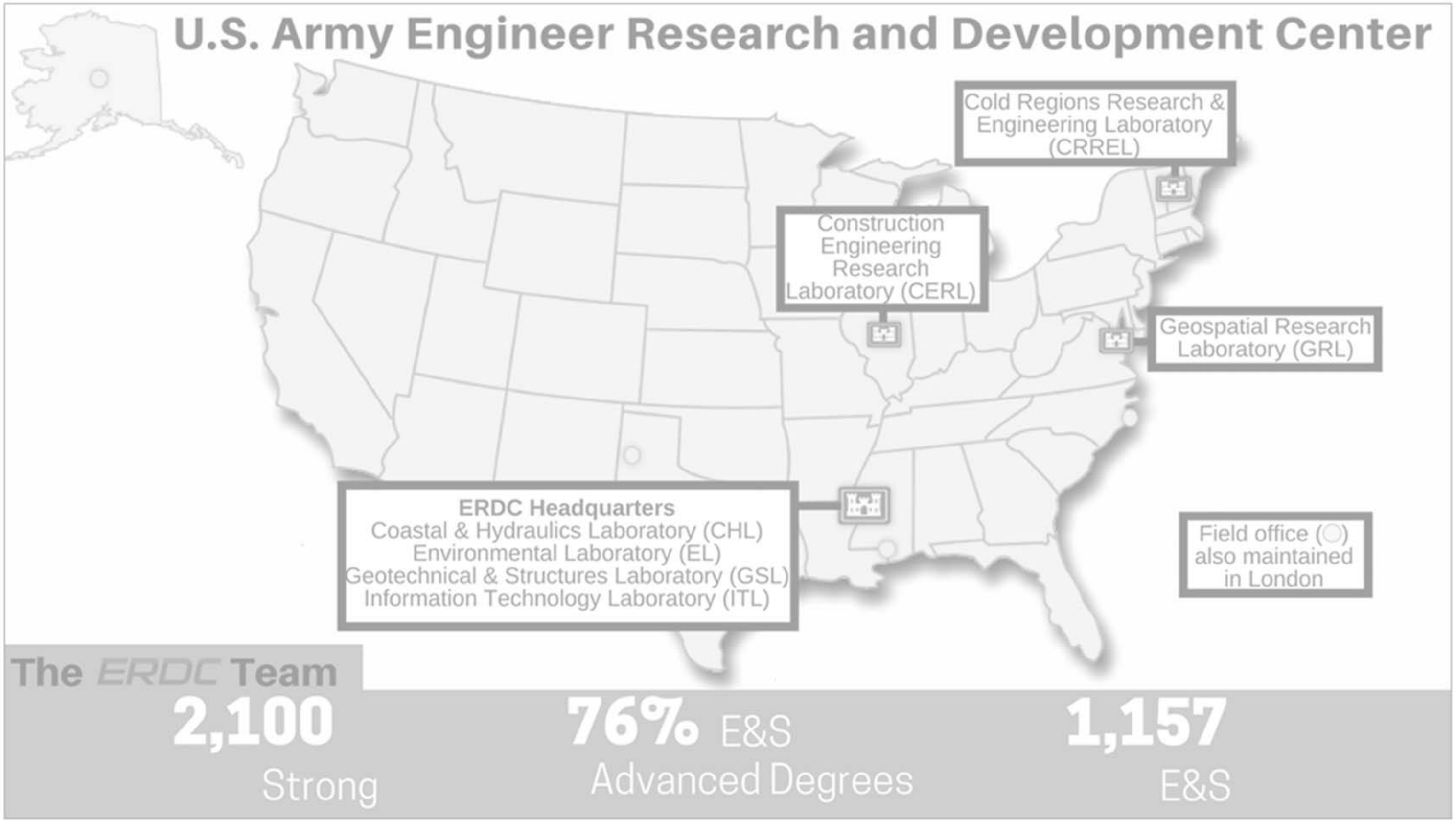
  - Implies 0.00 – 0.45 mg/ha/d NQ transformation near surface

Potential Impact

Nitrification should be accounted for as a near surface process



Questions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