Biochar: Is It The Fix All We Have Been Waiting For?

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Outline

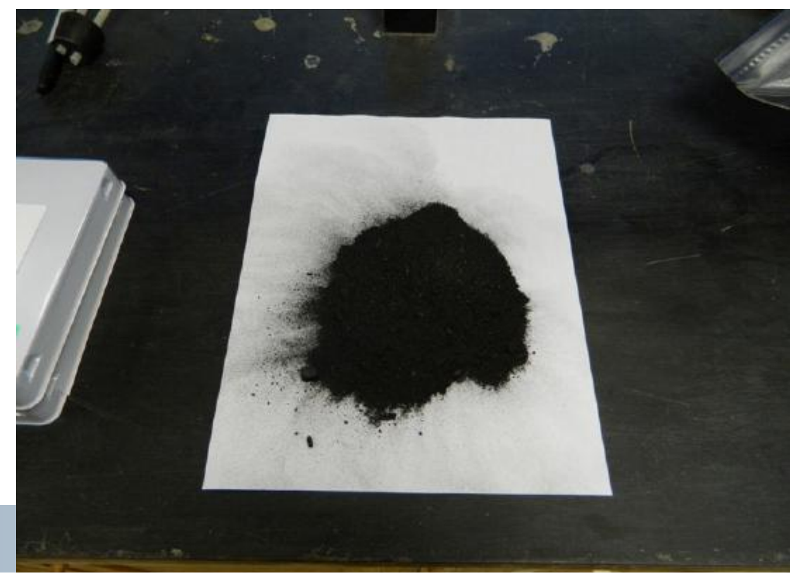
- Goals and Background
- Biochar application: Denitrifying Bioreactors
  - N_2O emissions and microbial abundance
- Real world application
- Cleaning up: Mitigating sulfate reduction

Goals

- How can we optimize denitrifying bioreactor performance to maximize their benefits and minimize the downside?
  - Mitigate additional pollutants
  - Reduce GHG emission (N_2O)
- Research objectives:
  - Maximize denitrification
  - Minimize greenhouse GHG emissions
  - Prevent harmful intermediaries

Background

- Biochar has been proven successful in reducing the mobility of N and P in agricultural soils
  - Results in stable material with high AEC and CEC
- Reduced N_2O emission from soil has also been observed in response to biochar
- Increase in the abundance and activity of denitrifying microorganisms

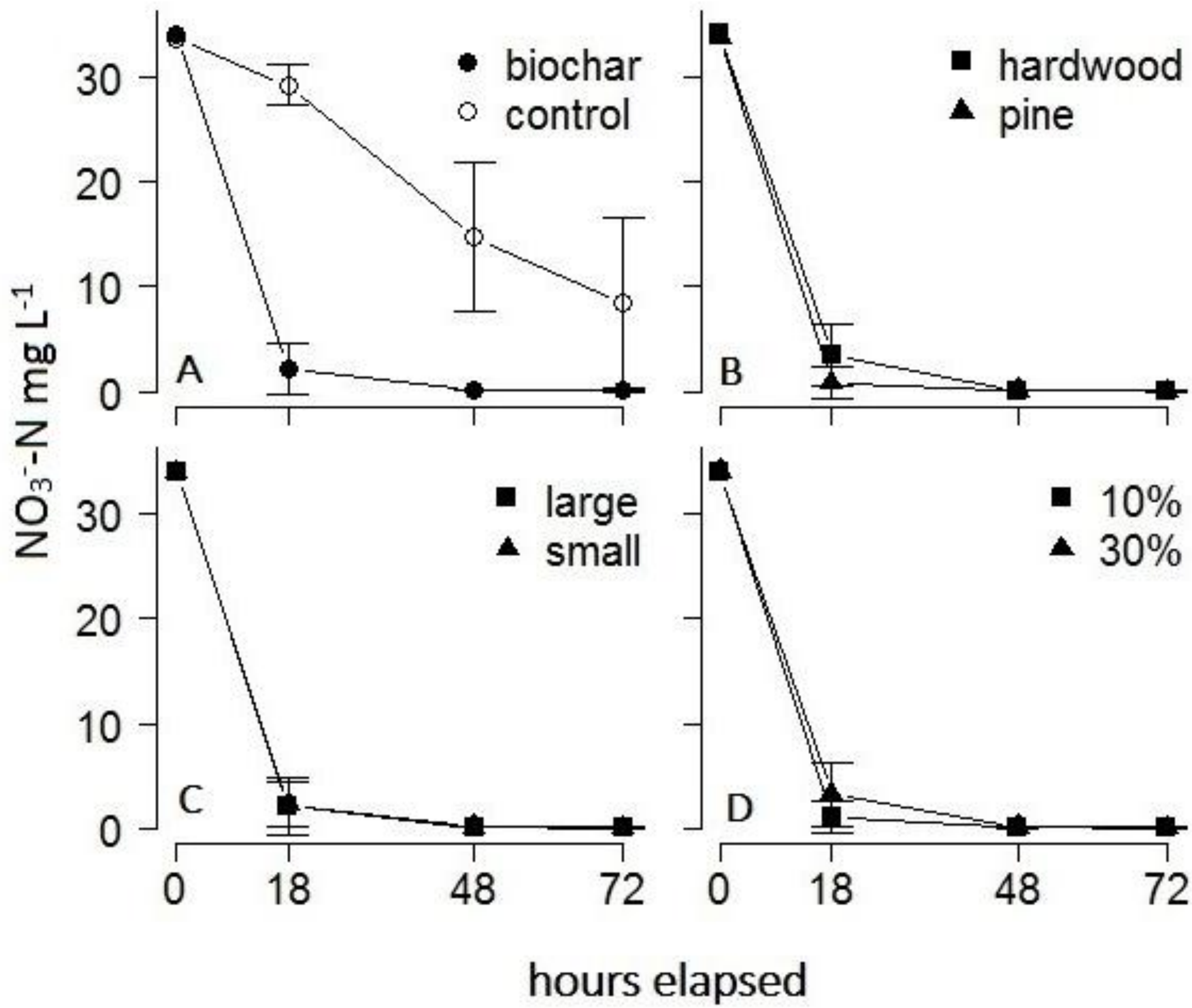


Study 1

- Determine if biochar addition can enhance N and P removal while simultaneously reducing N_2O production without substantially altering biofilter hydraulic properties
  - Different biochar feedstocks and ratios tested
  - NO_3^-, NH_4^+, PO_4^{3-} measured in aqueous samples
  - N_2O extracted from column head space and analyzed by GCMS
- Denitrifying enzyme activity ($NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$) mediated by four reductase enzymes *narG* → *nirK* → *nirS* → *nosZ* →

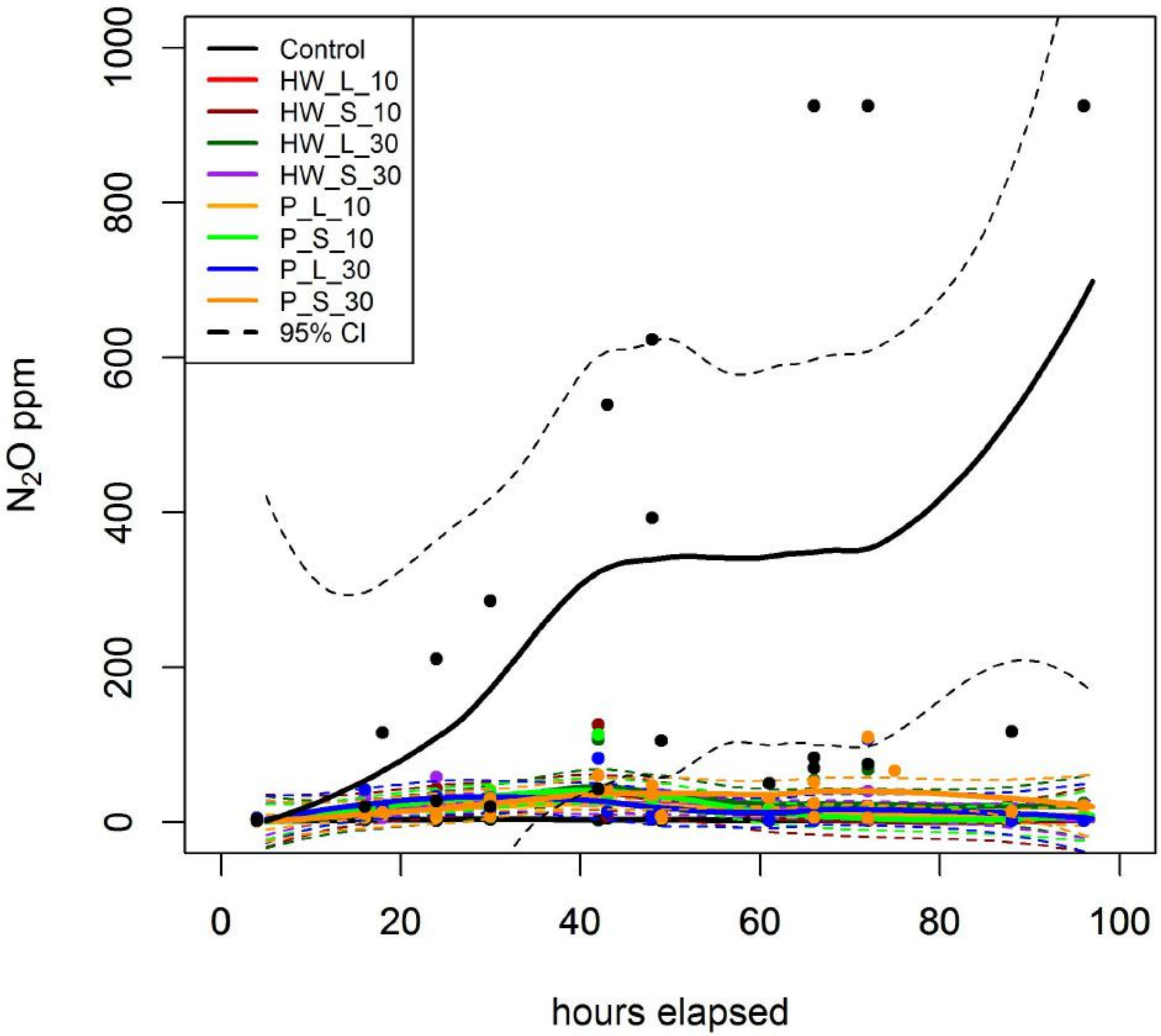
Bock et al 2015a,b *JEQ*
Davis et al 2016 *JEQ in review*

Results

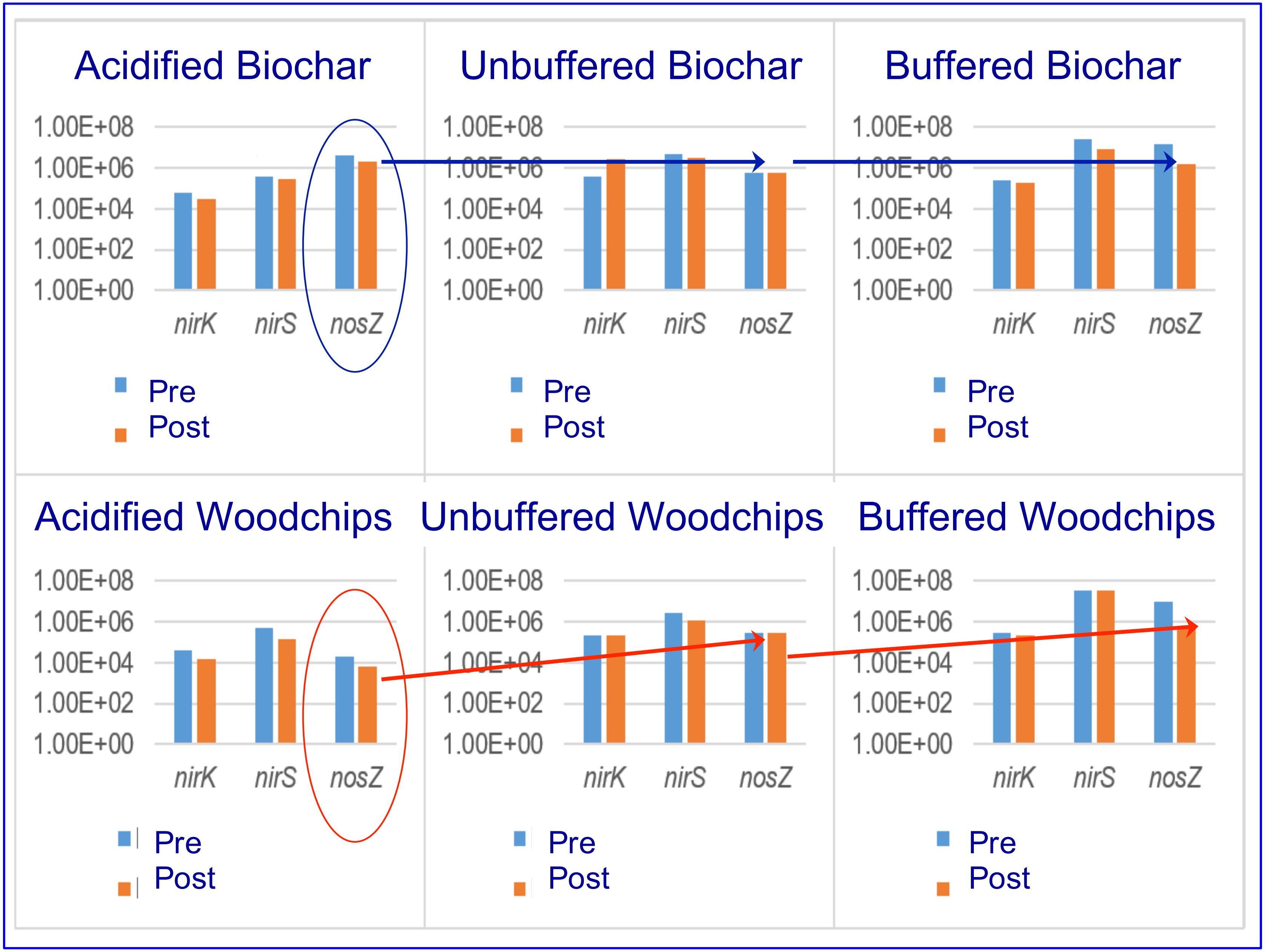


Bock et al 2015a *JEQ*

Nitrous Oxide



Results-Microbial Data



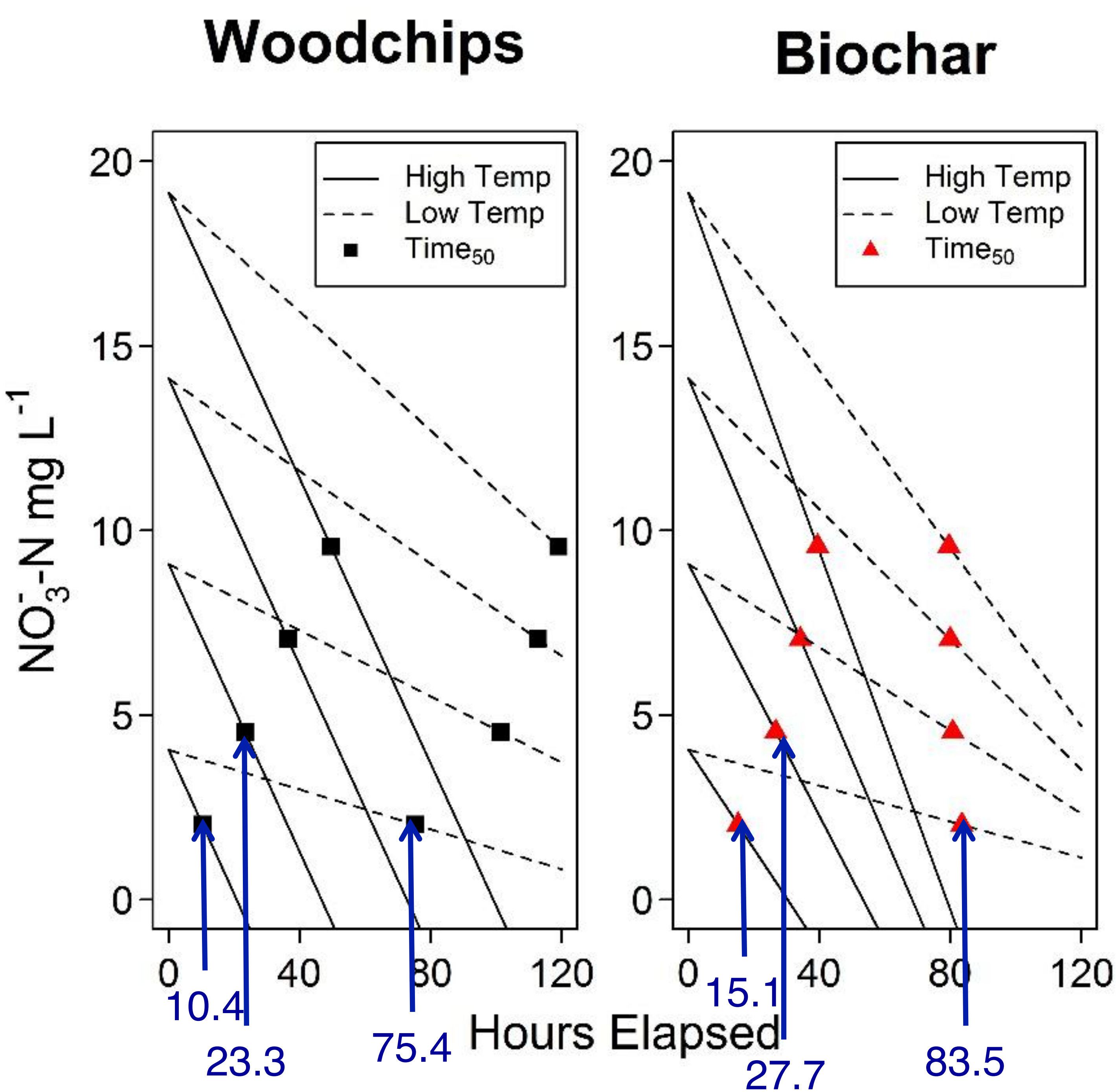
Davis et al 2016 *JEQ in review*

Why the big N_2O difference? Enzyme Activity

- Coupled physiochemical/biological effect
  - Biochar buffers the pH above 6.5
    - pH levels below 5.5 have been shown to increase N_2O emissions
      - N_2O reductase (nosZ) is more sensitive to low pH than other enzymes in the denitrification process
    - Indeed nosZ reductase was significantly inhibited in the woodchip only (low pH) treatment
      - More than an order of magnitude less nosZ expression

Study 2. Field Application

- Paired biofilters woodchip and woodchip+biochar biofilters
- Series of events of varying concentrations (5-20 mg N L^{-1}), residence times (2-80hr), and temps
  - NO_3^-, NH_4^+ measured in aqueous samples



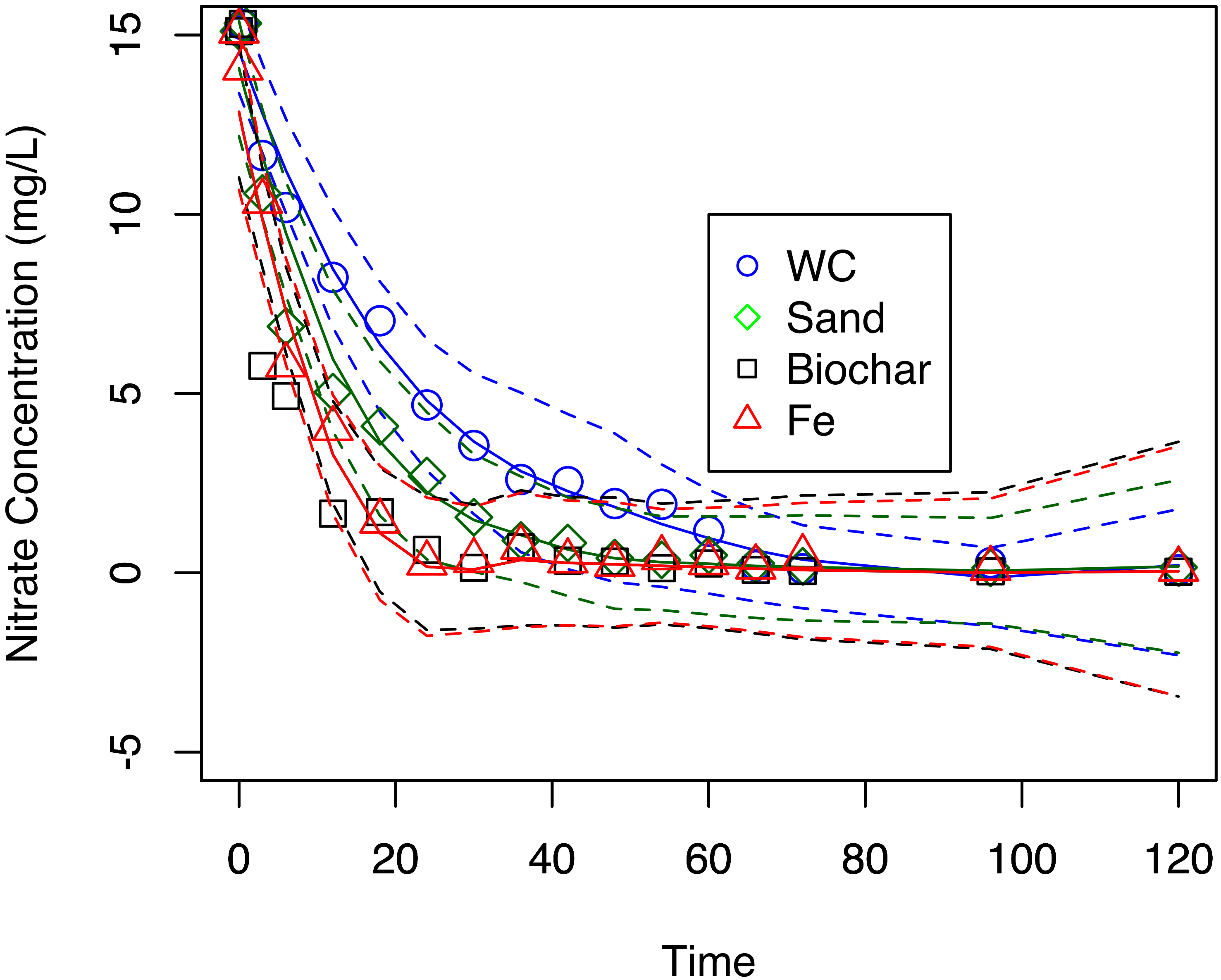
Bock et al 2015b *JEQ*

Study 3. Downsides

- Previous experiments revealed that the rapid rate of NO_3^- removal creates conditions that favor sulfate reduction (e.g. biochar lowers redox)
- Develop method to poise the system above the redox potential of sulfate reduction
  - As NO_3^- is depleted SO_4^2 reducers will outcompete NO_3^- reducers and drive the redox down to that of SO_4^2 reduction
  - Fe(III) can buffer this redox potential change because bacterial Fe(III) reduction takes place at a higher redox potential than does SO_4^2 reduction

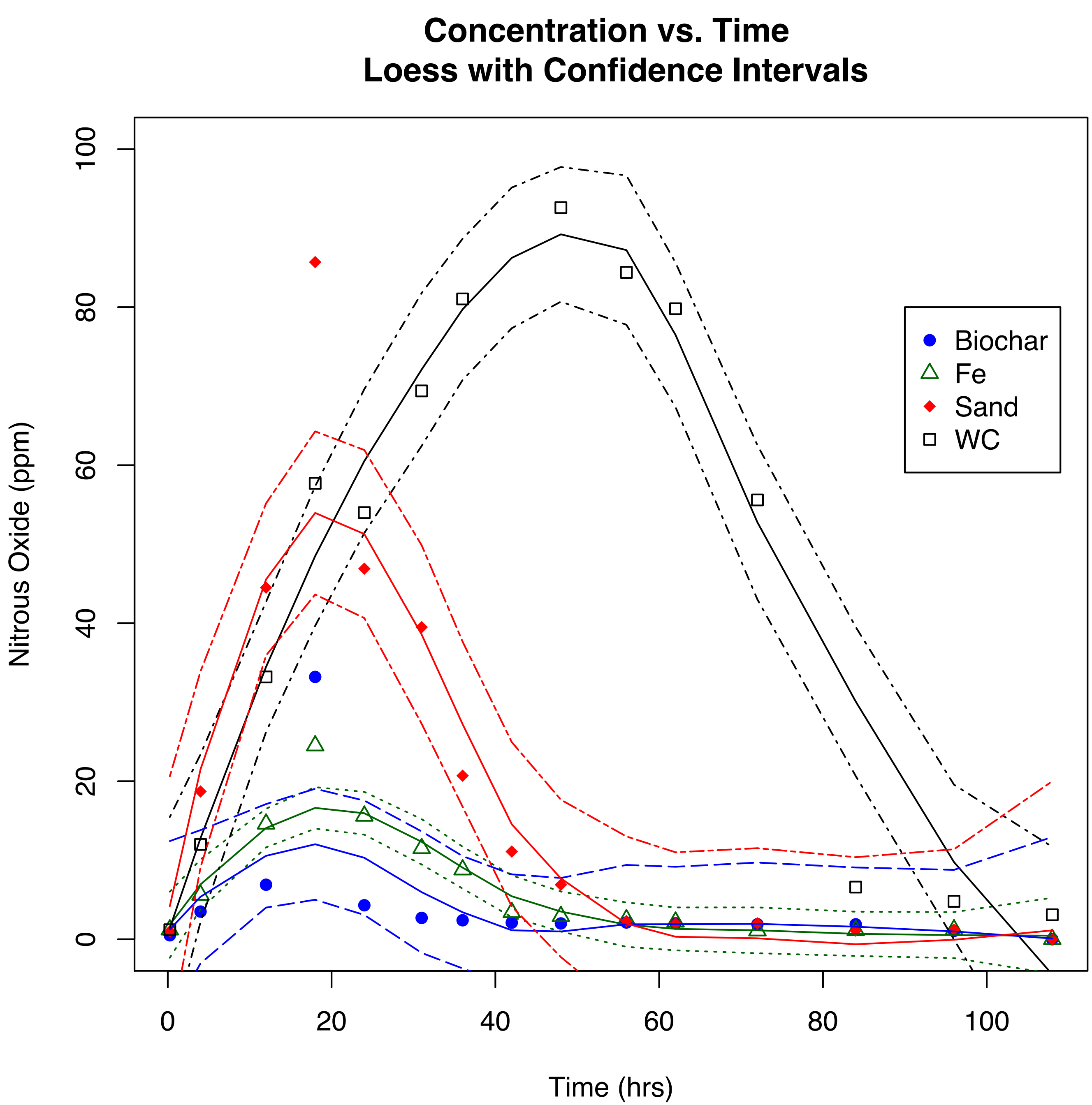
Easton et al 2015. *Ecol Eng*

Concentration vs. Time
Loess with Confidence Intervals

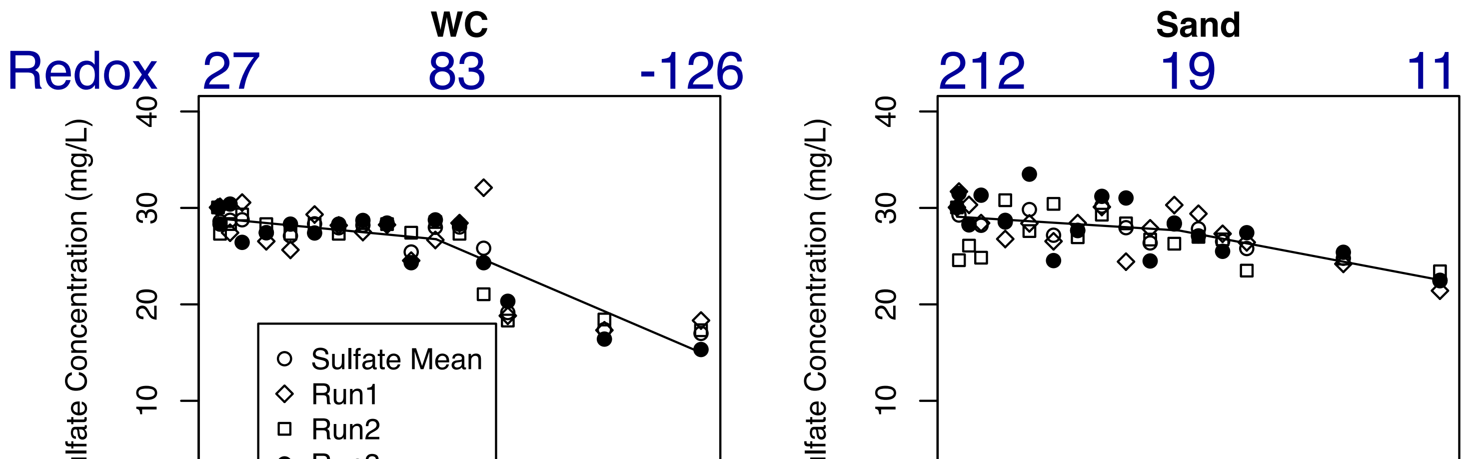


Treatment	T_{50} (hr)
WC	16.10 a
Sand	5.45 b
Biochar	3.05 c
Biochar + Fe	4.25 c

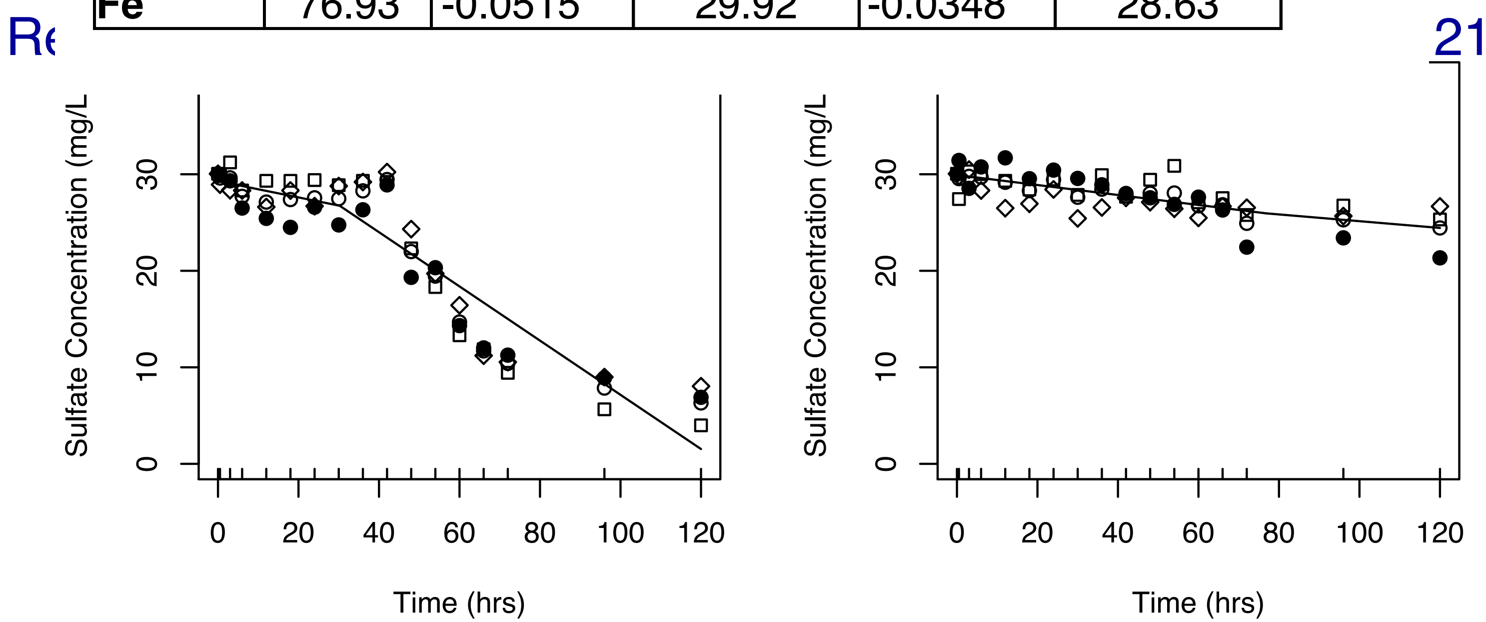
Easton et al 2015. *Ecol Eng*



Treatment	N_2O (ng)
WC	638 a
Sand	218 b
Biochar	61 c
Fe	43 c



	Slope Break (time)	Slope1	Estimated Intercept1 (conc)	Slope2	Estimated Intercept2 (conc)
WC	54.06	-0.0624[NS]	28.90	-0.1786**	36.43
Sand	55.30	-0.0292[NS]	29.10	-0.0795*	32.06
Biochar	30.14	-0.0832**	29.28	-0.1802***	35.21
Fe	76.93	-0.0515[NS]	29.92	-0.0348[NS]	28.63



Current Work

Conclusions

- Opportunities exist to enhance N removal and treat other contaminants
  - Biochar enhances N removal rates and reduced N_2O emissions
    - Buffers pH
    - Increased microbial abundance
  - Unfortunately it also causes sulfate reduction
    - Substrate engineering can mitigate consequences
- Future work will explore application to other contaminants
  - Pharmaceuticals, pesticides, pathogens