Influence of activated carbon on microbial transformation of chlorinated solvents and explosives

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OVERVIEW OF THE PRESENTATION

Why do we need to know more about in situ activated carbon and electron donors

Combined reactions, and how in situ activated carbon relates to past work

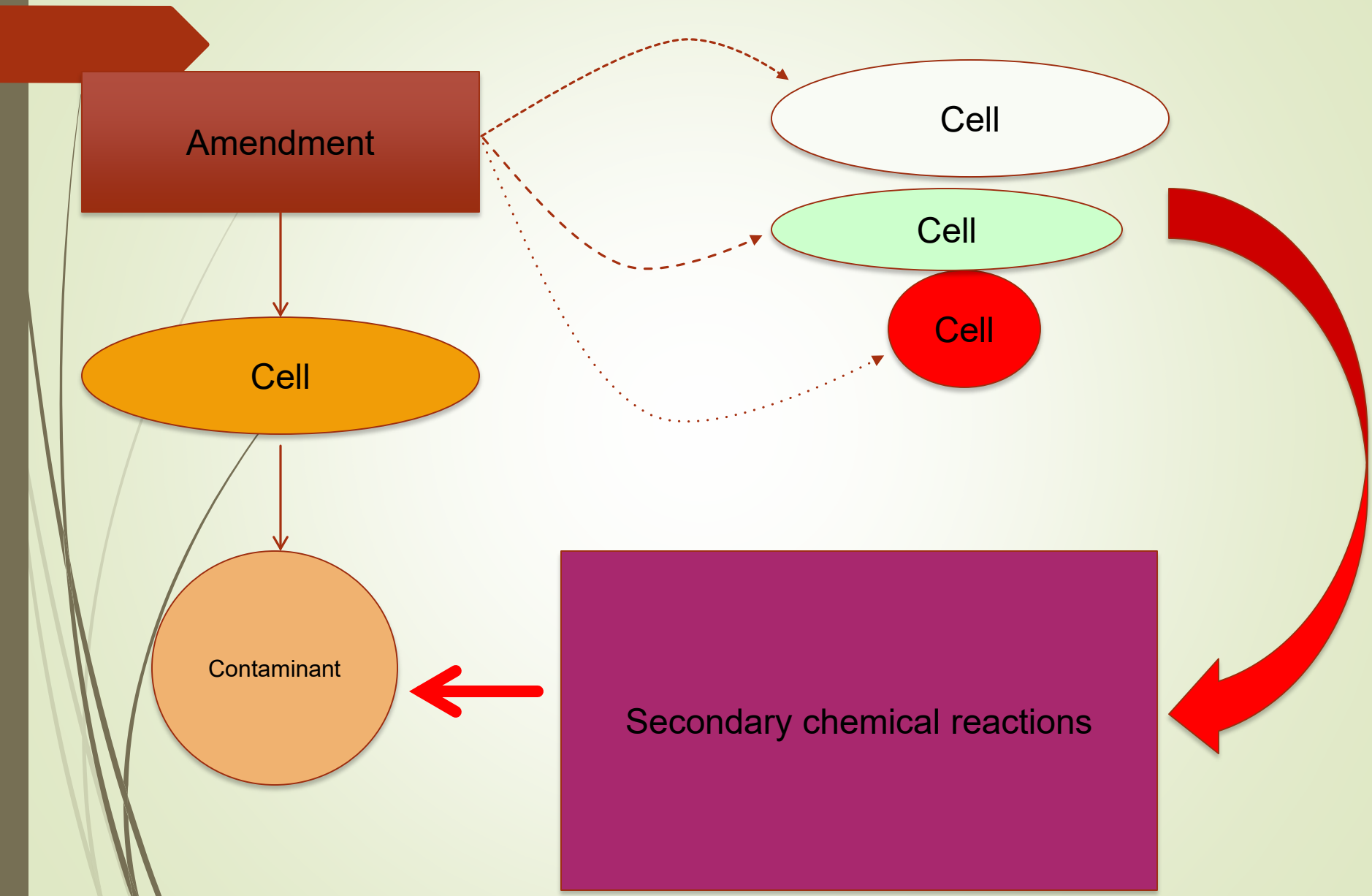
Experimental Data

RDX both ex situ and in situ

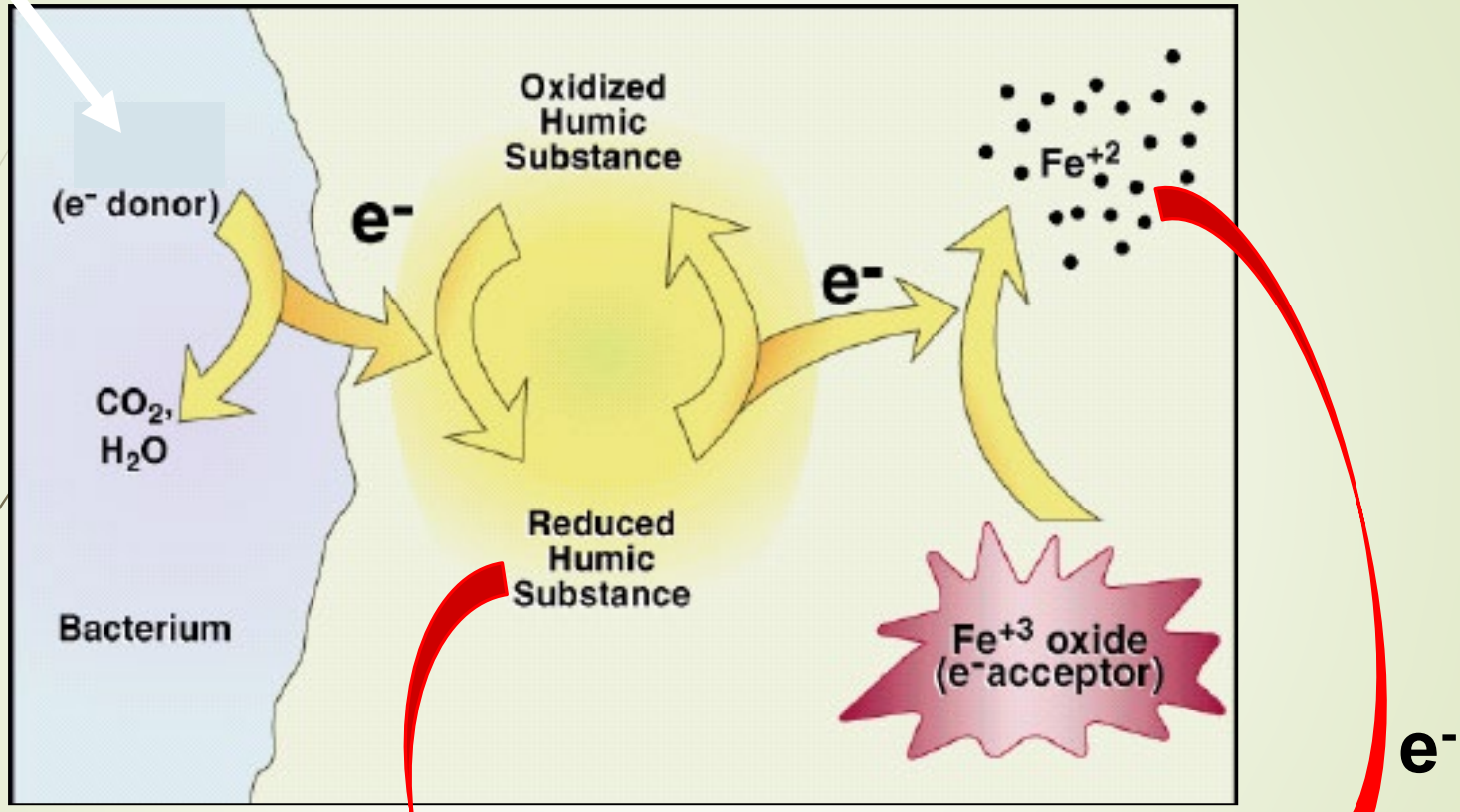
Chlorinated solvent remediation

CONCLUSIONS

Our expertise is combined reactions; what do we mean by that?

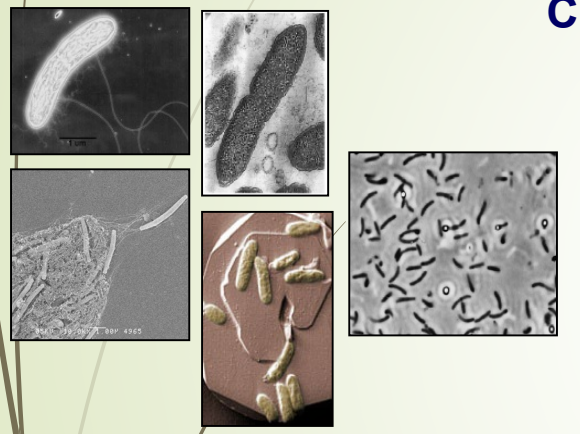


Electron donors can be contaminants or labile substrates



Reduced extracellular electron shuttles can transfer electrons to electronegative contaminants (organic and inorganic compounds)

Some combined reactions discovered by Dr. Man Jae Kwon:



Organic compounds

CO_2

Iron (EES) reducer

Fe(III)

Fe(II)

e- shuttle oxidized

e-shuttle reduced

Fe(II)

Fe(III)

e-

e-

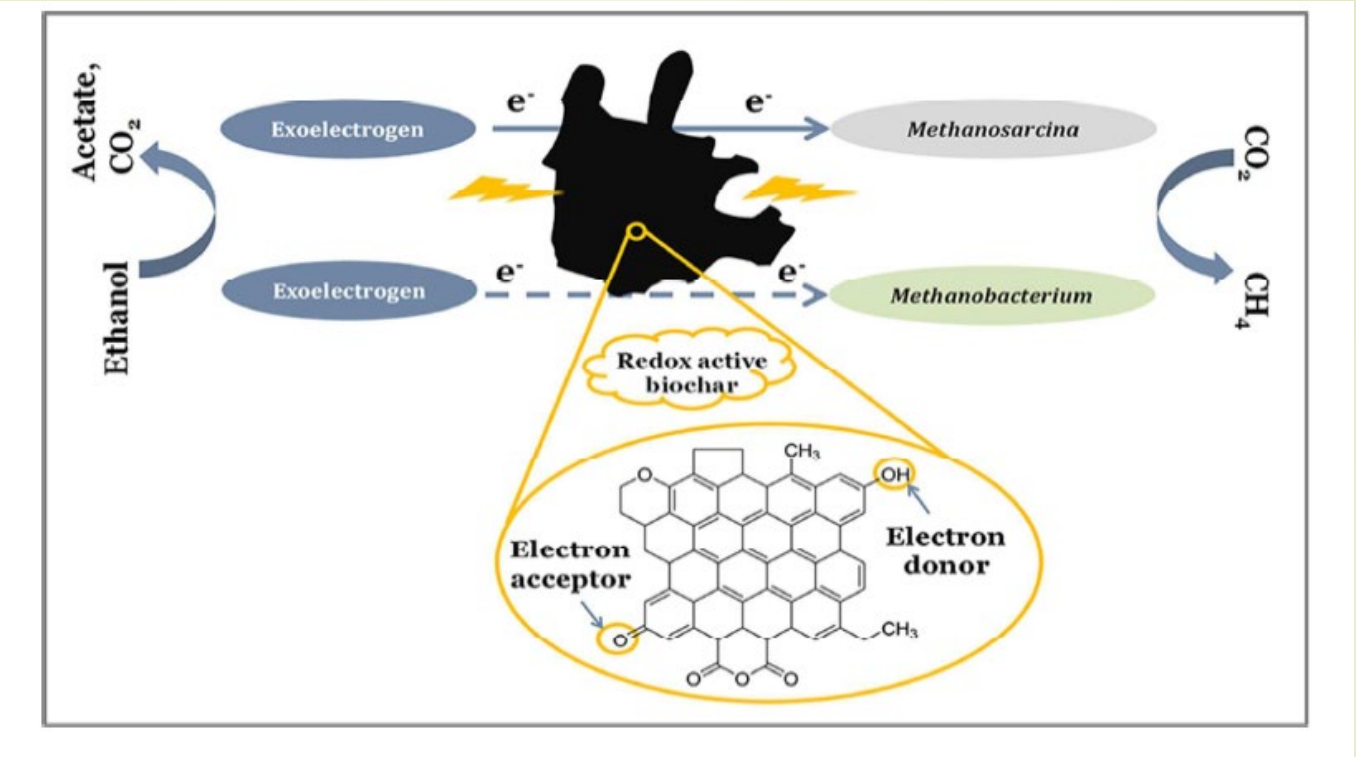
e-

e-

RDX and HMX reduction (to unstable metabolites)

ring cleavage

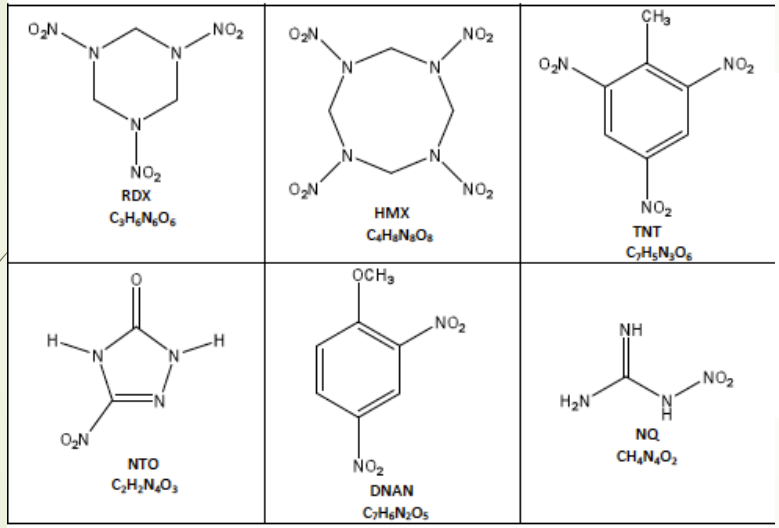
$HCHO, CO_2, N_2O$



The chemical structure of activated carbon allows for electron transfer through the structure

Biodegradation of GAC-Adsorbed RDX

Over 1,200 sites in the U.S. and 2,000 sites in Europe have been contaminated by explosives



Explosive	Molecular mass [g/mol]	Solubility in water [g/L]	Reduction potential [V]
RDX	222.12	38.9 mg/L (low to negligible)	-0.55
HMX	296.16	6.63 mg/L (low)	-0.66
TNT	227.13	insoluble	N/A
NTO	130.07	12.8	N/A
DNAN	198.13	sparingly soluble	-0.40
NQ	104.07	3	-0.70

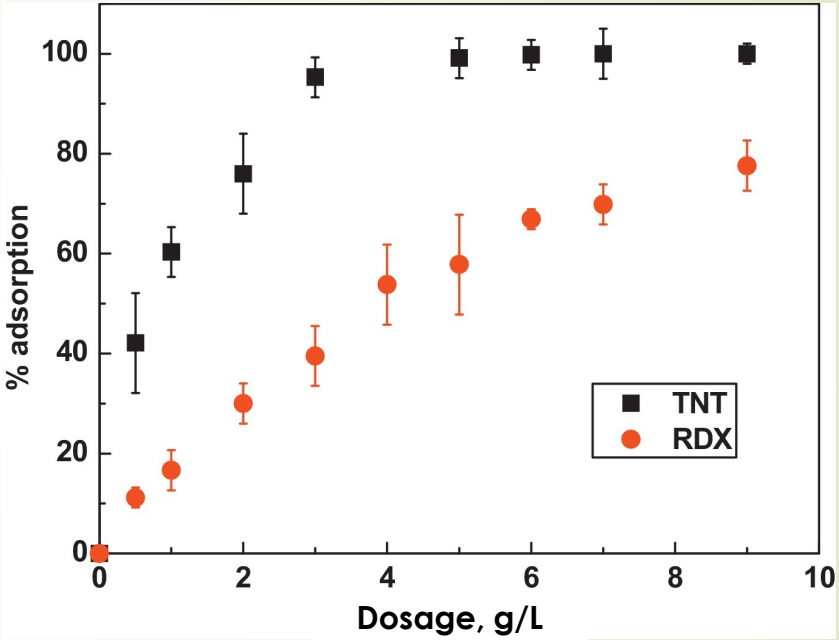
RDX is a possible human carcinogen (the lifetime health advisory in drinking water is 2μg/l)

HMX may damage the central nerve system (the lifetime health advisory in drinking water is 0.4mg/l)

IM such as 2,4-dinitroaniosole and 3-nitro-1,2,4-triazole-5-one (NTO) are currently being investigated in novel explosives composites for DoD use

Niedzwiecka and Finneran , RSC ES:WR&T, 2015, V1(1), Page 34-39

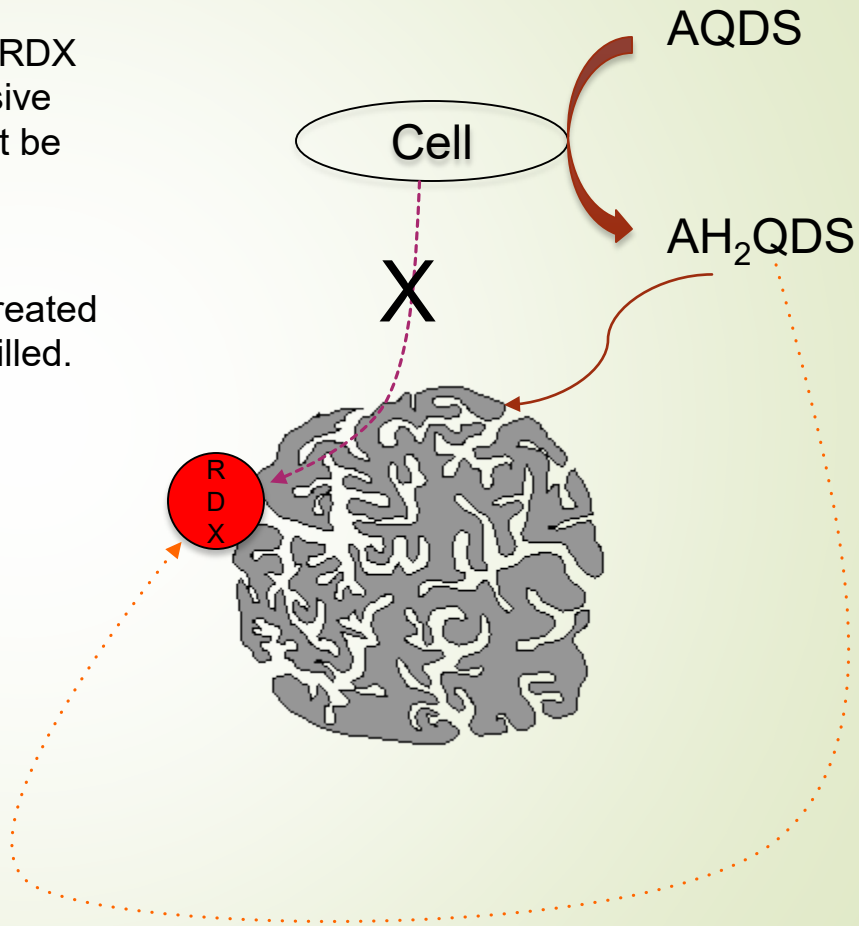
GAC sorbs explosives easily



Pump and treat using granular activated carbon (GAC), the most common form of porous carbon, is the “de facto” treatment strategy utilized in RDX remediation.

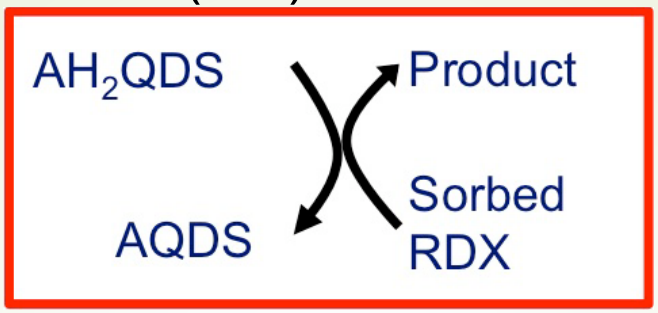
Adsorption of over 12% (w/w) RDX per GAC constitutes an explosive hazard; therefore, carbon must be continually replaced.

The spent carbon is typically treated as hazardous waste and landfilled. This process is very costly.

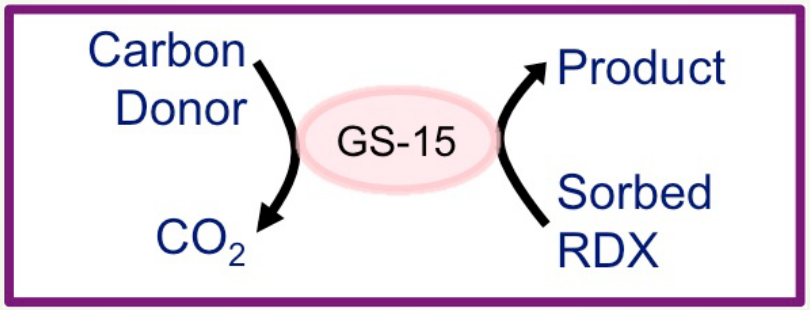


Electrons are added to sorbed RDX

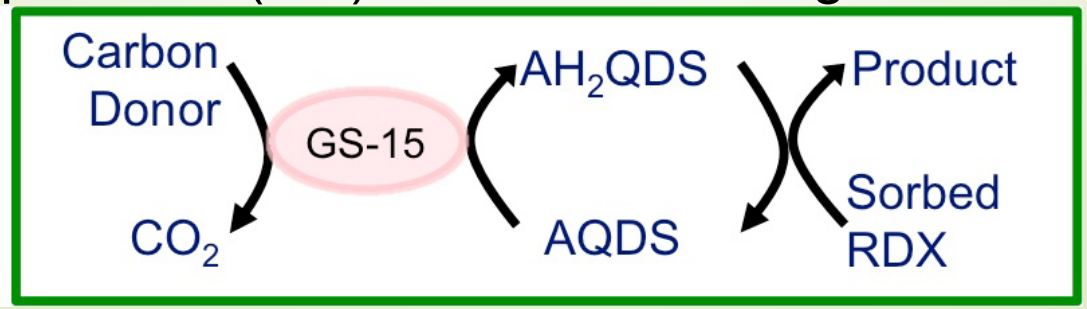
Treatment Approach 1 (T-1): Chemical Reduction System



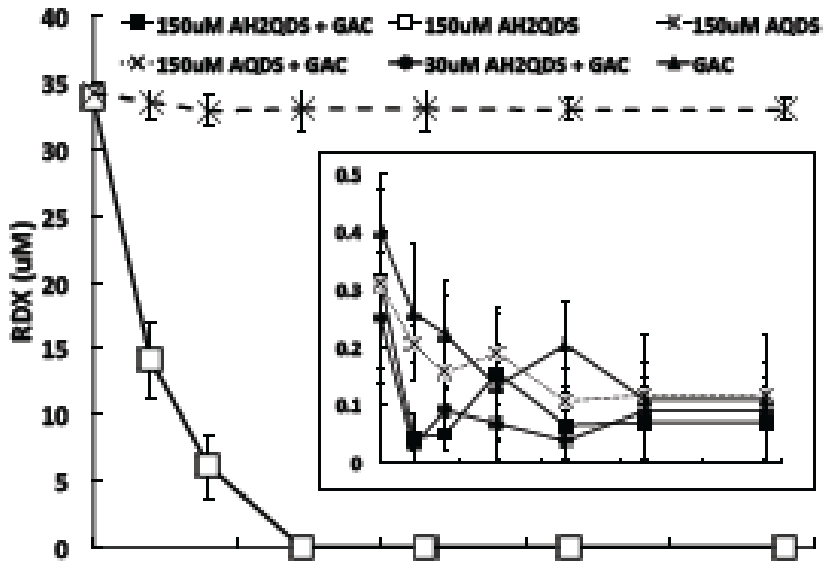
Treatment Approach 2 (T-2): Biological Reduction System

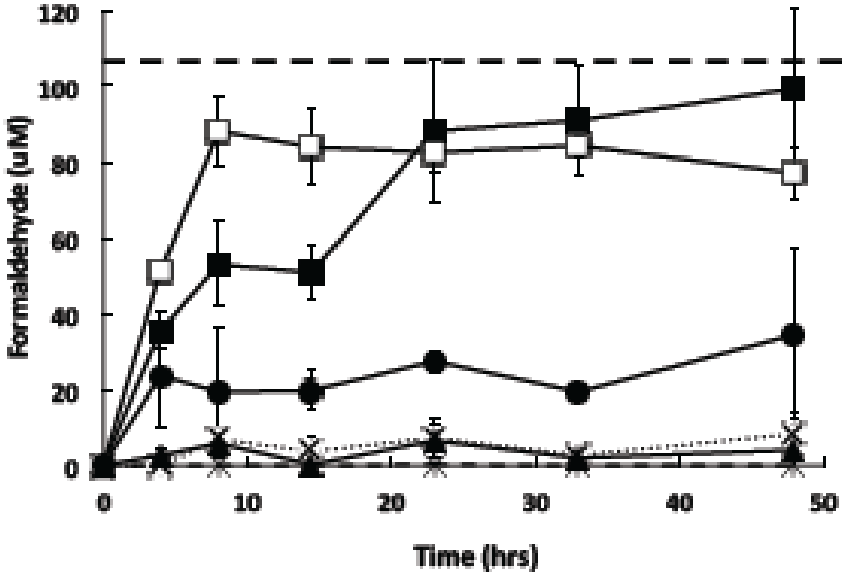


Treatment Approach 3 (T-3): Chemical-Biological Reduction System



Adsorption of RDX to GAC and HCHO production from AH_2QDS amendment



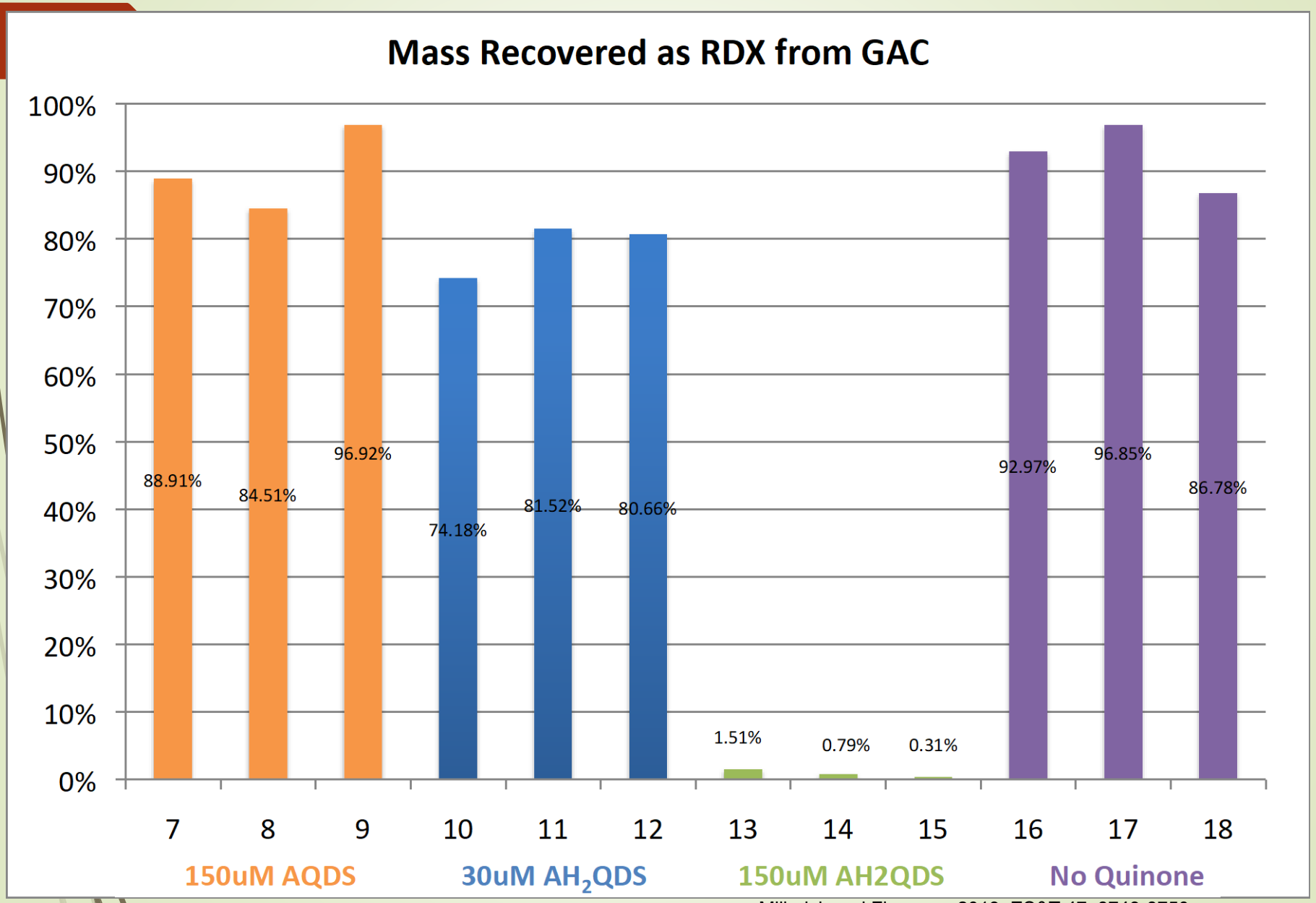


RDX rapidly adsorbs to minimal GAC mass, and mass transfer back into the aqueous phase is negligible unless a strong organic extractant is added

HCHO formation agrees with the predicted 3:1 stoichiometry when AH_2QDS is present in "excess" relative to the RDX adsorbed to GAC

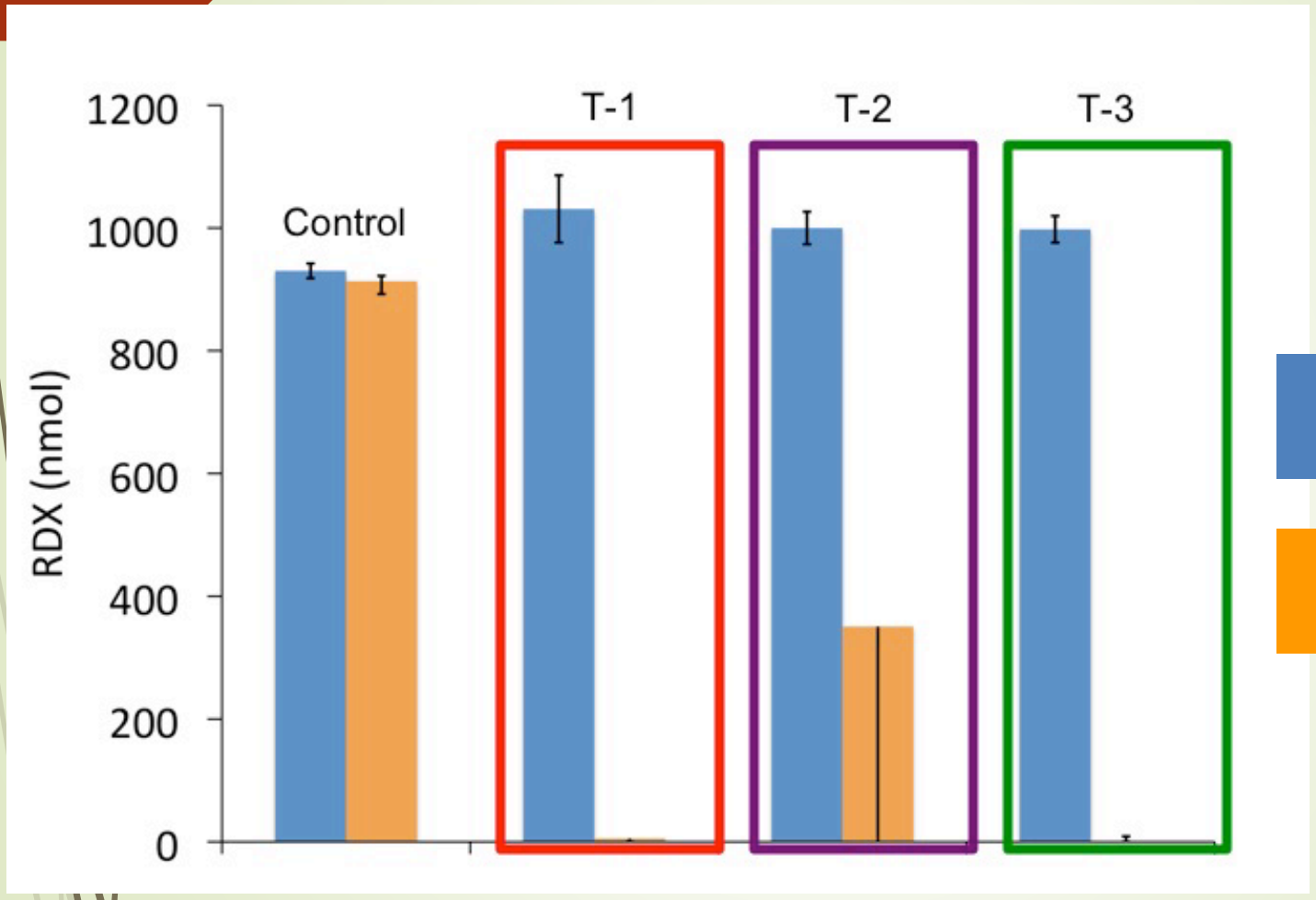
Millerick and Finneran, 2013, ES&T 47: 8743-8750

Post-treatment RDX recovered from GAC after extracting with 100% EtOH



Millerick and Finneran, 2013, ES&T 47: 8743-8750

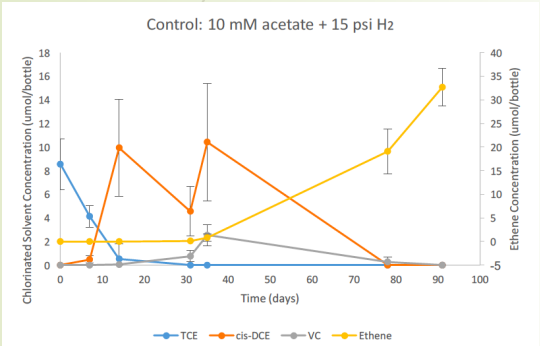
Systems that incorporate both quinone and quinone-reducing bacteria consistently reduce RDX

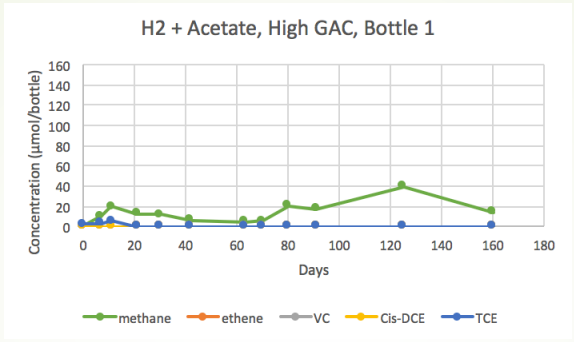


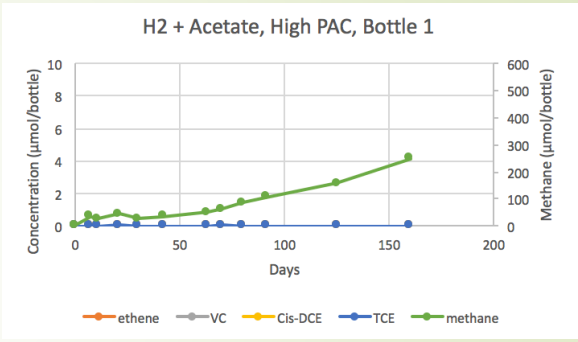
Influence of activated carbon on TCE biodegradation

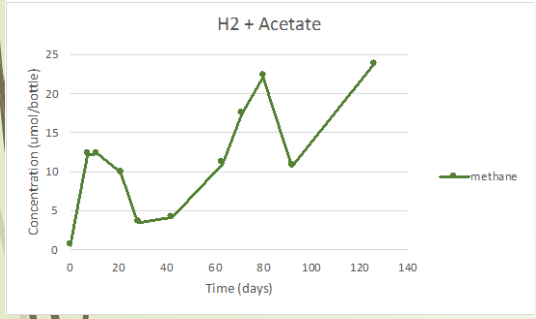
H_2 + Acetate Amended (High Carbon Loading)

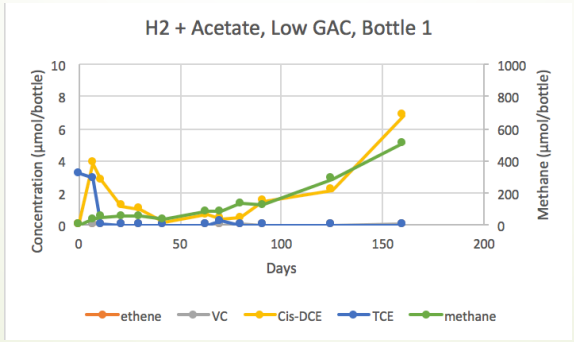
No Activated Carbon	Granular Activated Carbon	Powdered Activated Carbon

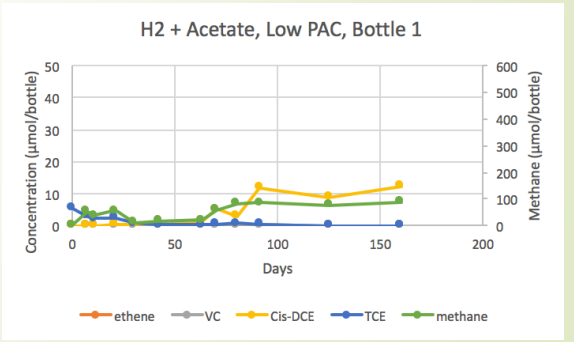












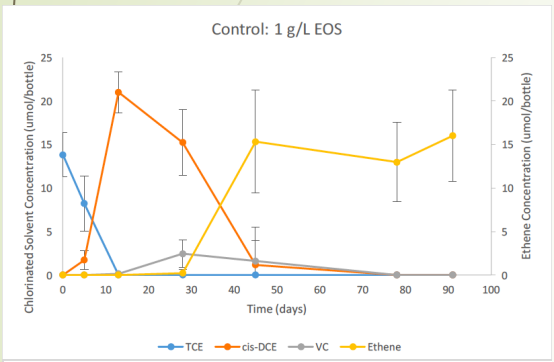
Lipid Amended (High carbon loading)

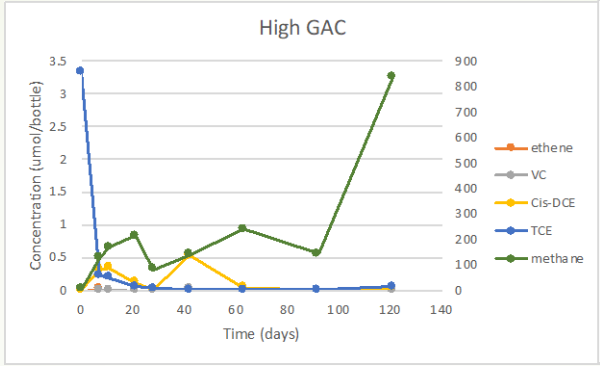
Lipid Amended (High carbon loading)

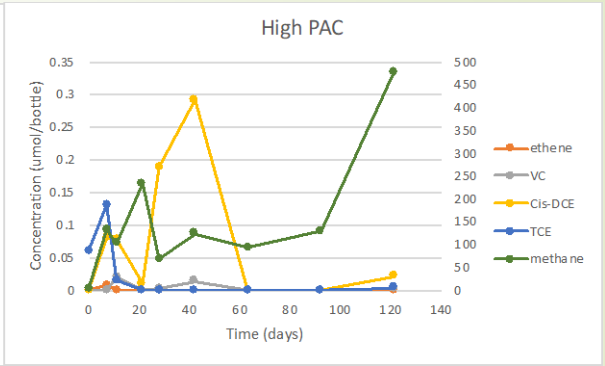
No Activated Carbon

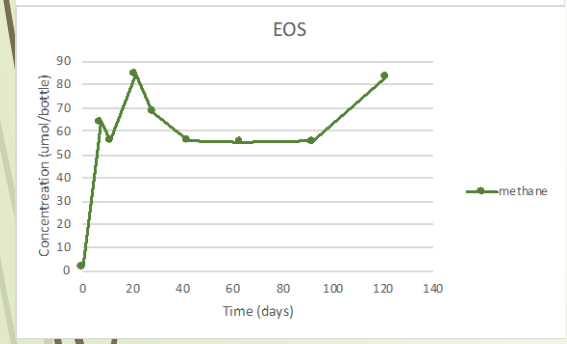
Granular Activated Carbon

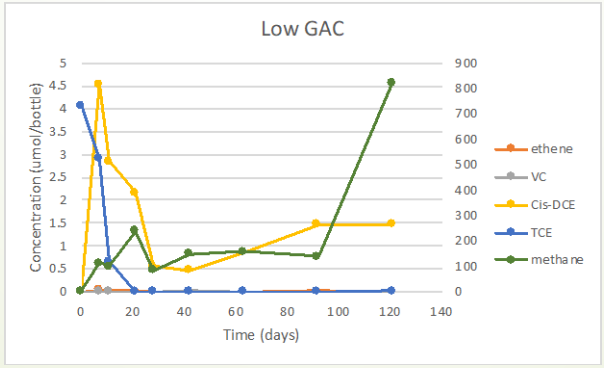
Powdered Activated Carbon

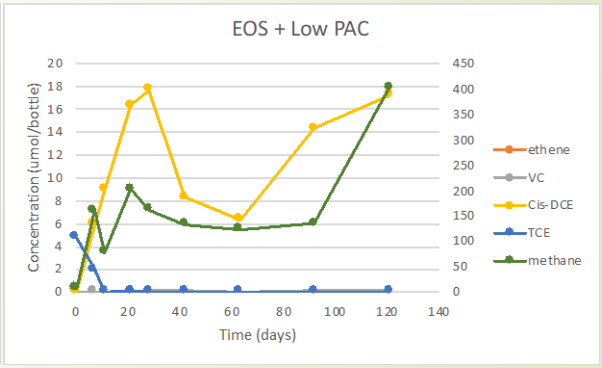




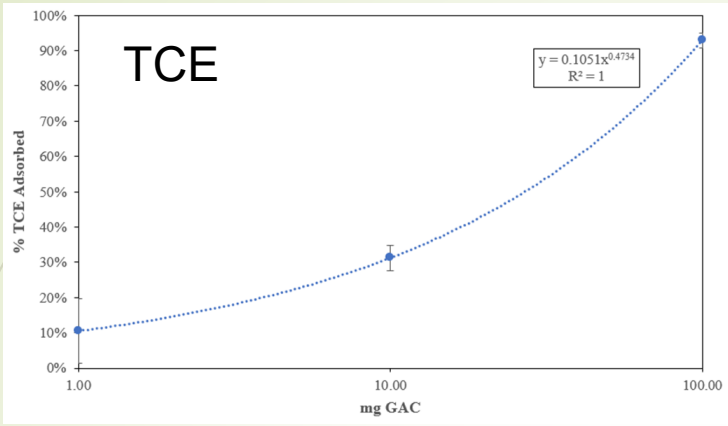


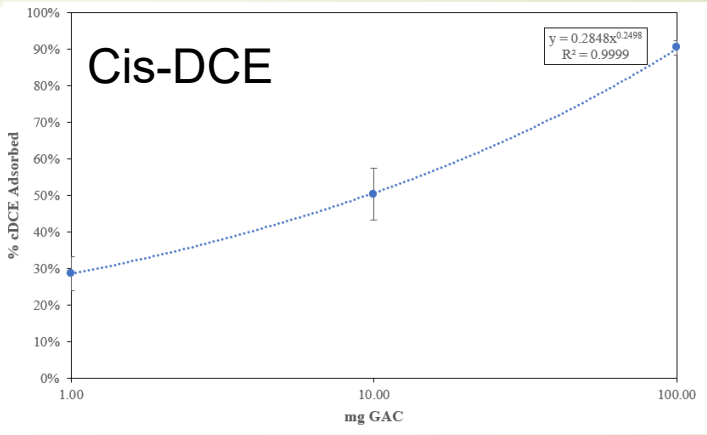


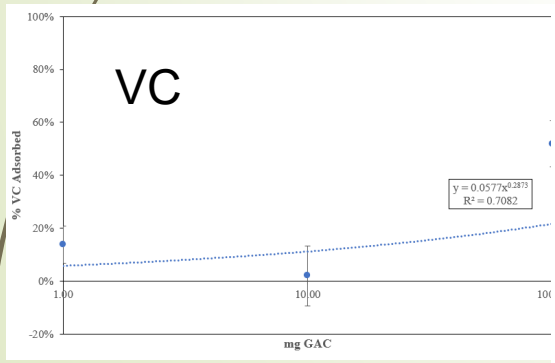


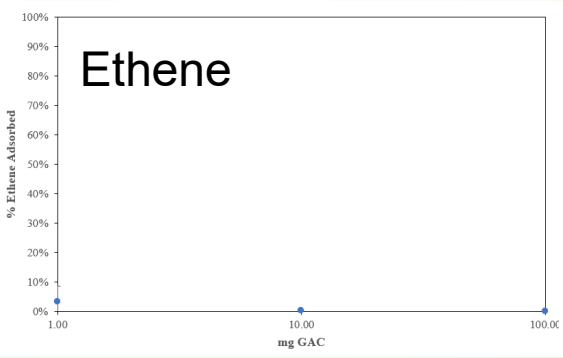


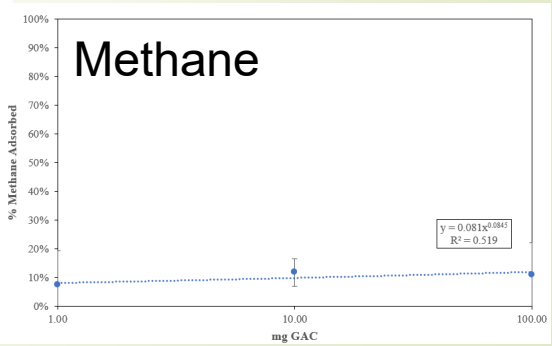
Adsorption Studies, Low to High Carbon Loading





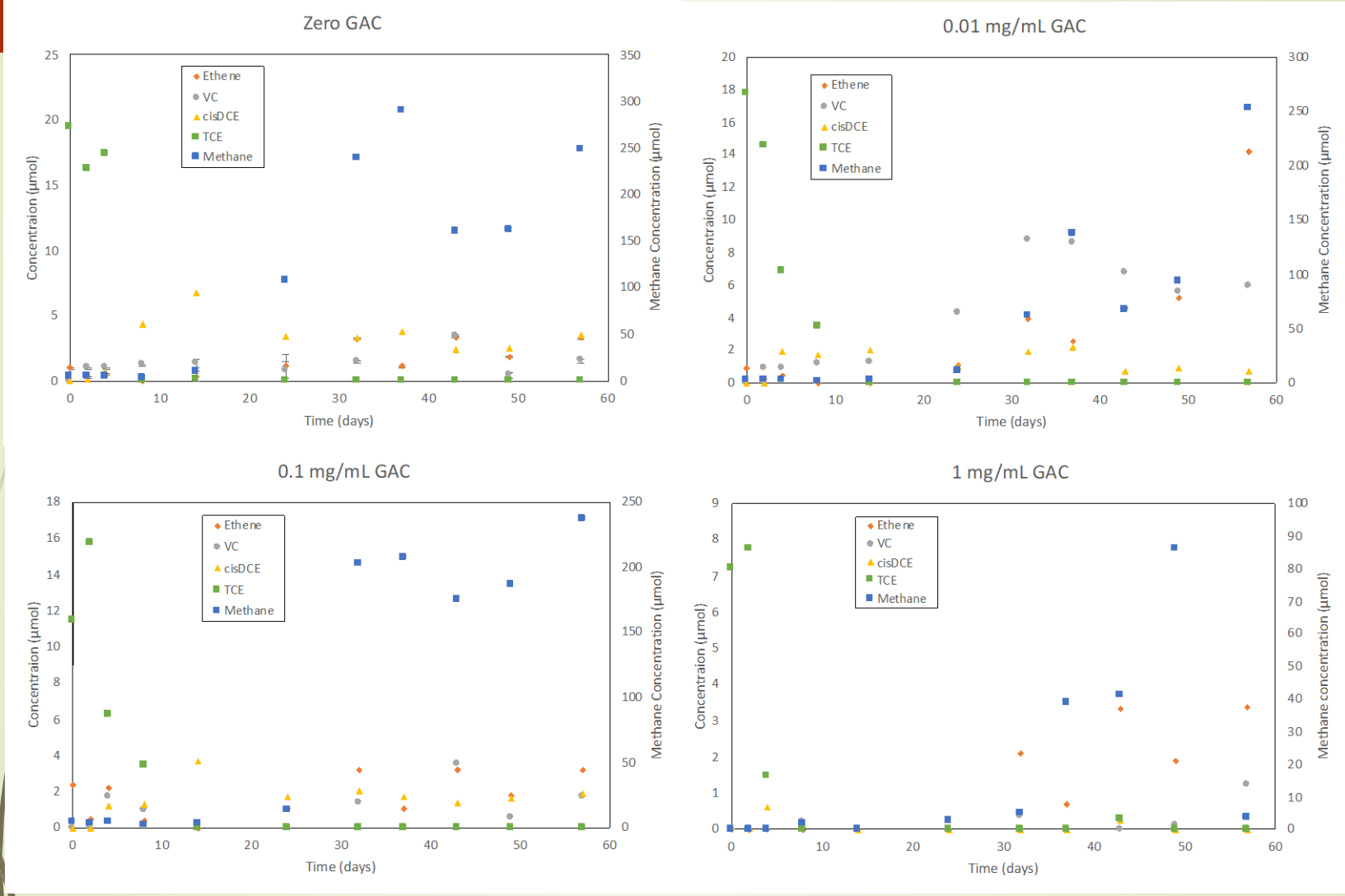






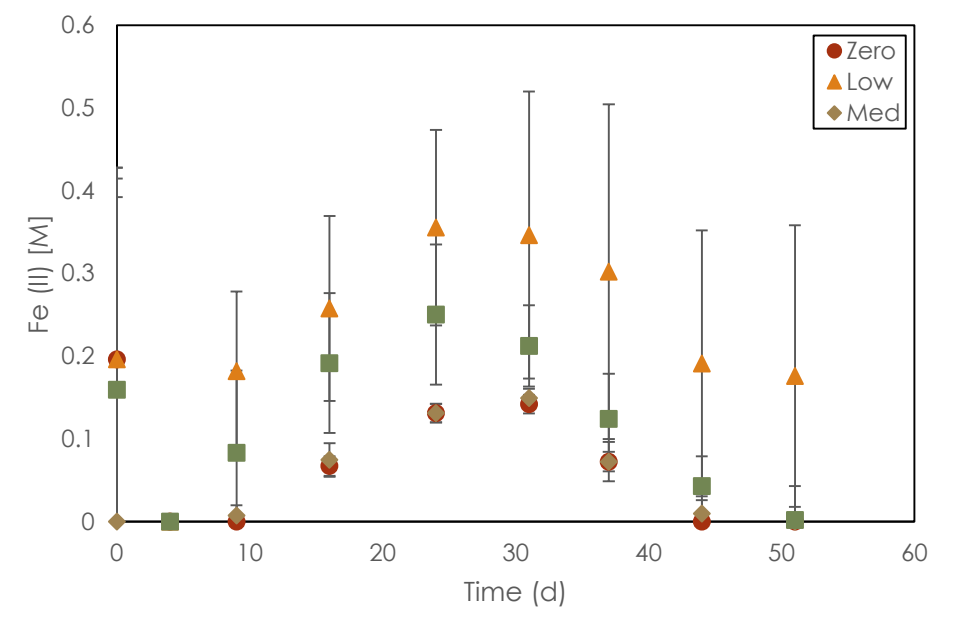
I.E. If the lesser chlorinated compound VC and the end-product ethene are produced, they will not adsorb and will be quantifiable in the aqueous/headspace fraction

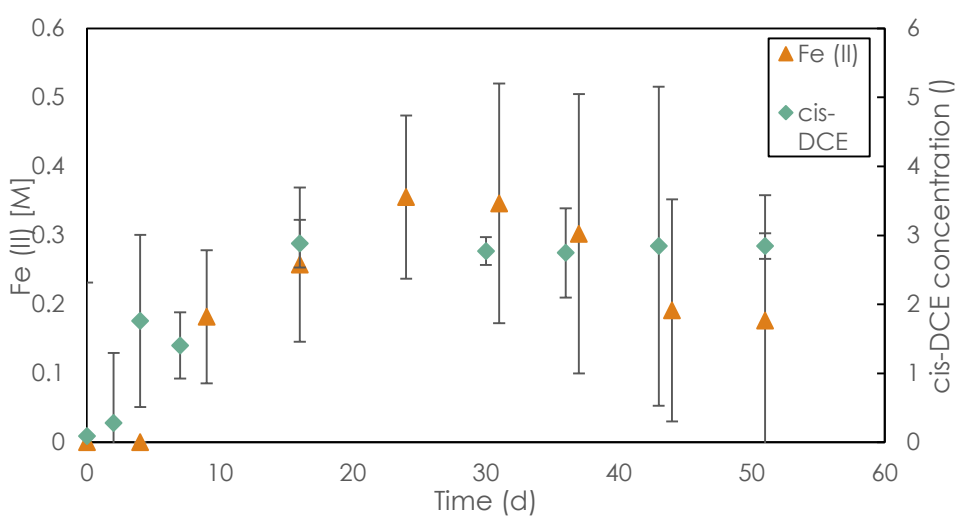
TCE Reduction with H_2 + Acetate as the Electron Donor

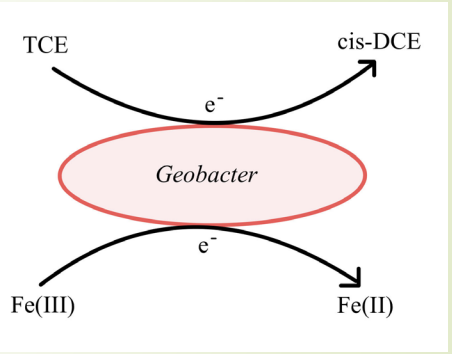


Data suggest an activated carbon sweet spot, in which there is adsorption but also degradation; it falls off as loading gets higher

Is the optimal activity mediated by Fe(III) reduction and the initial reduciton to cis-DCE?







Conclusions

- In situ activated carbon is very good at sorbing contaminants (which was expected); however, data are lacking as to effectiveness with secondary degradation reactions
- Data indicate that RDX (and other nitrated explosives) may be good candidates for use with activated carbon
- Data indicate that TCE is a poor candidate for use with high masses of in situ activated carbon – the complete reductive dechlorination pathway is inhibited, most likely by mass transfer limitations
- Lower masses do not inhibit TCE reduction (complete), and it is possible it is stimulatory at specific mass/volumes loadings (which may be lower than typically applied)
- Data again suggest that Fe(III) reduction and dechlorination are linked, this time via cis-DCE generation
- All strategies have a time & place – the goal is to refine each strategy and/or technology so it is most effective on a site-specific basis

Acknowledgments

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