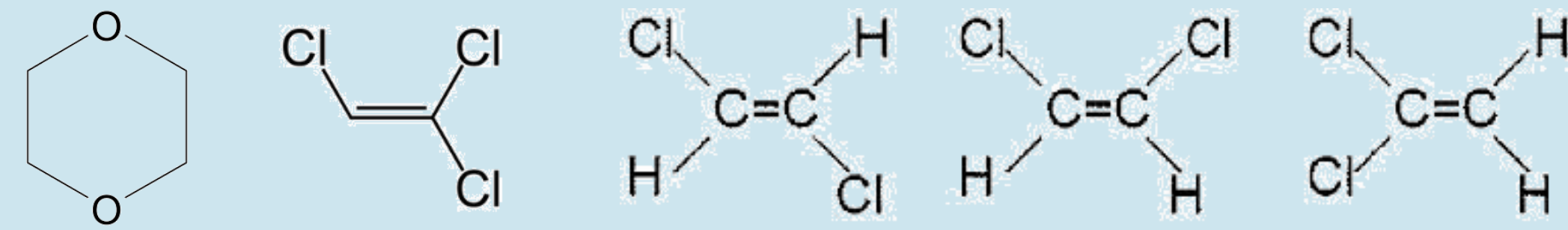


Using aerobic cometabolic biodegradation and groundwater recirculation to treat 1,4-dioxane and co-contaminants in a dilute plume

Introduction

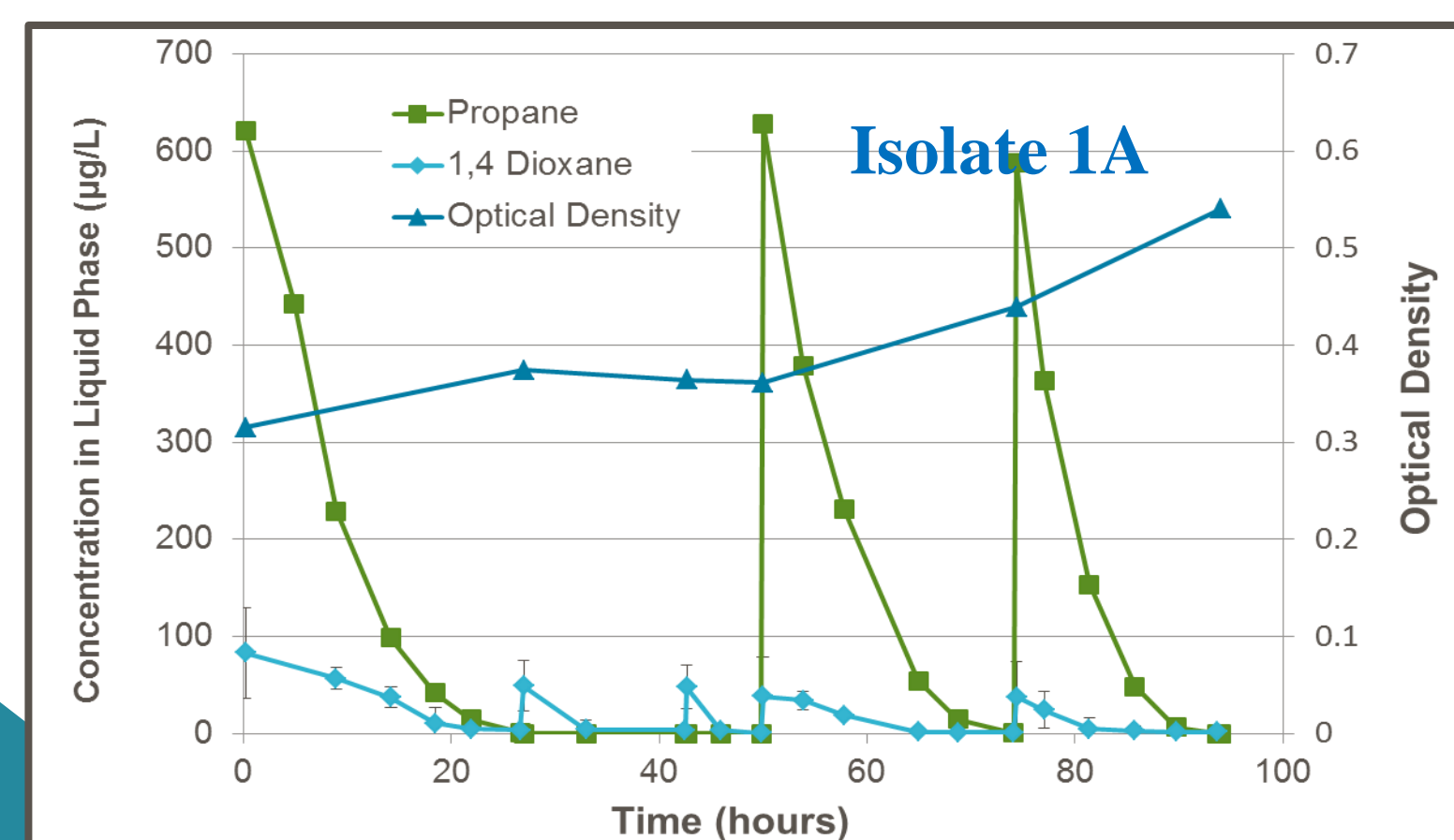
Groundwater impacted by chlorinated solvent compounds can also be impacted by 1,4-dioxane (1,4-D) because of its use as a solvent stabilizer. Treatment of groundwater (GW) impacted by 1,4-D at low concentration (< 200 ppb) is often required at solvent sites. The **main objective** of this project is to demonstrate the capability of **aerobic cometabolic biodegradation (ACB)** for treating 1,4-D and its common co-contaminants in GW using the GW recirculation approach.



Can all propane-oxidizing bacteria degrade 1,4-D?

Microorganisms capable of degrading 1,4-D are not ubiquitous in the subsurface. Several propane-oxidizing cultures in the literature demonstrate good cometabolic degradation potential of 1,4-D and trichloroethene (TCE). We used eight propane-oxidizing cultures to assess how their 1,4-D degradation capability varies.

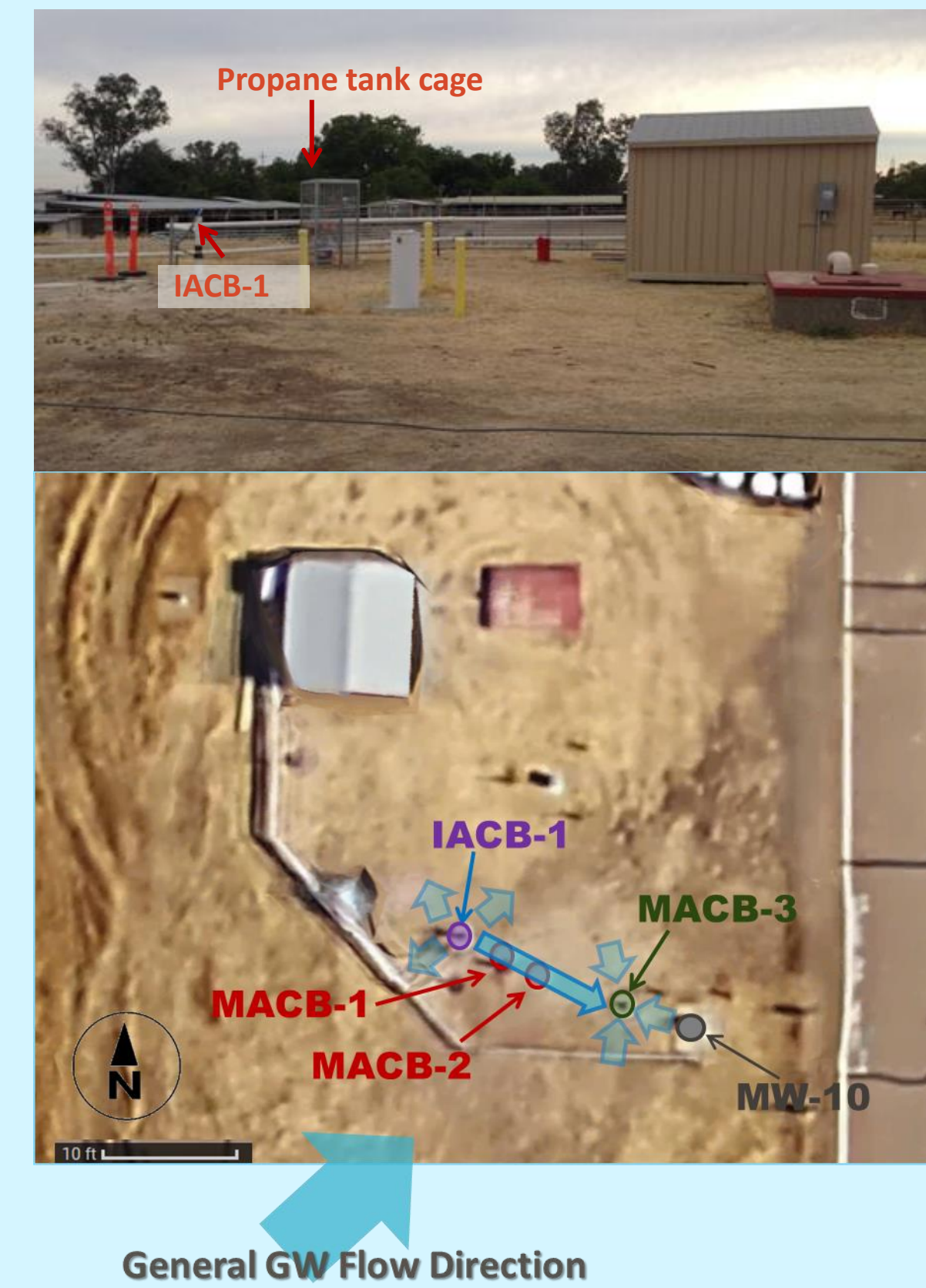
Commercially available strains		MTBE & TBA degradation strains maintained by NCSU	
<i>Brevibacterium ketoglutamicum</i>	Little 1,4-D cometabolic biodegradation capacity	Isolate 1A (<i>Mycobacterium</i> sp.)	Good 1,4-D cometabolic biodegradation capacity
<i>Arthrobacter rubellus</i>		Isolate 3A	
<i>Rhodococcus jostii</i>		Isolate 4C1	
<i>Thauera butanivorans</i>		Isolate 4C2	
<i>Arthrobacter</i> sp. (ATCC 27779)	OK		



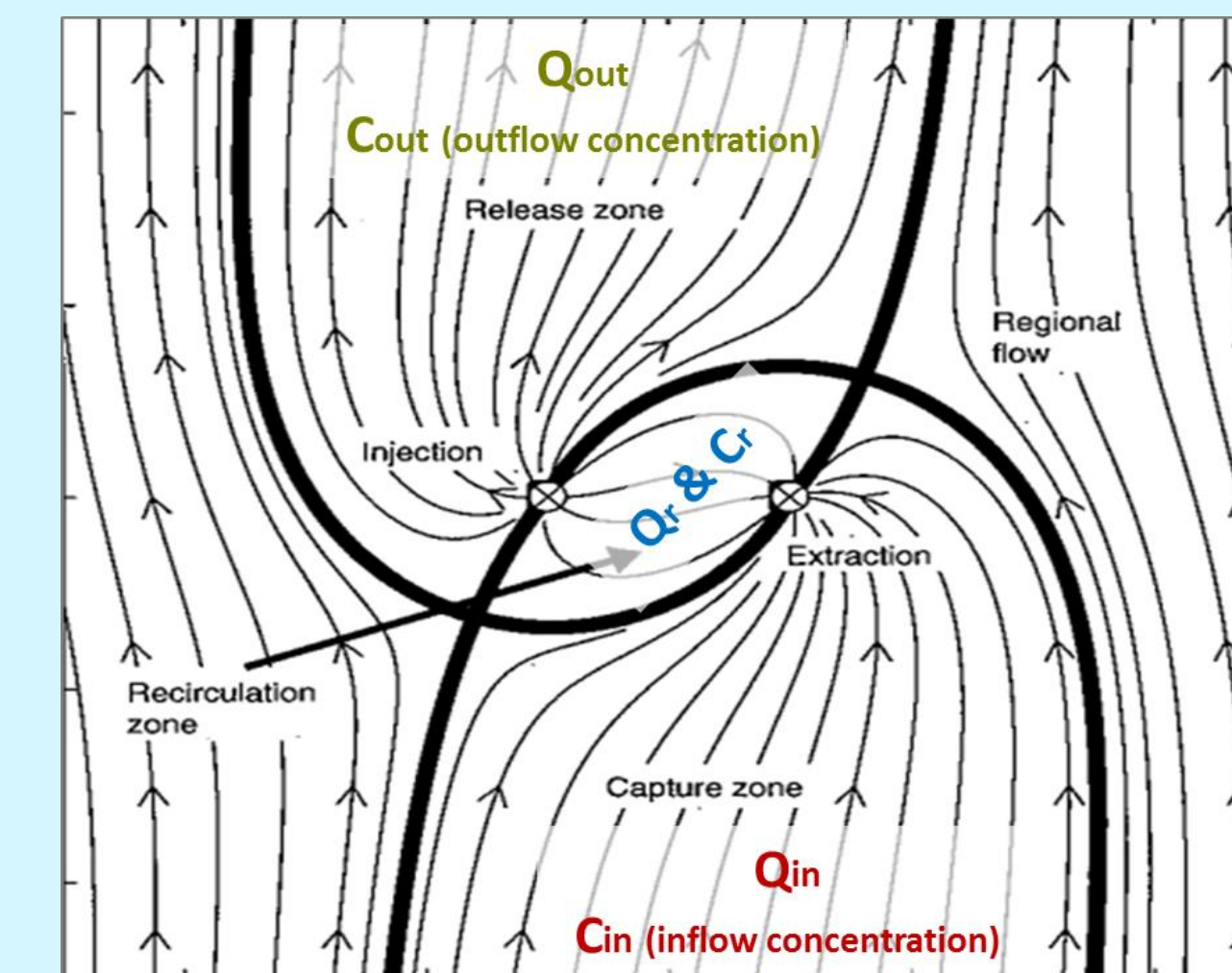
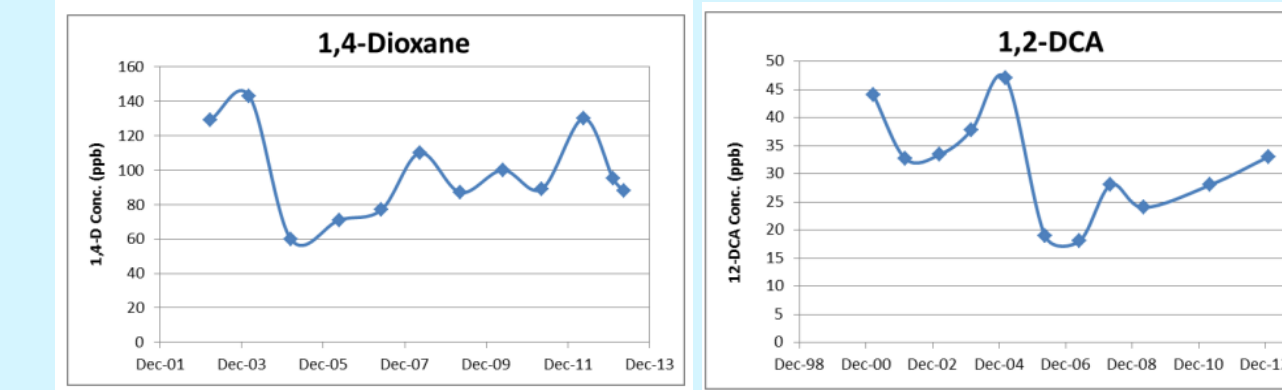
- Sustained 1,4-D ACB was observed using the Isolate 1A culture.
- The activity of ACB can last at least 24 hours without substrate addition.
- A longer duration of starvation test indicates that the culture can sustain the ACB activity over a week.

Field testing site

We selected the Operable Unit D (OU D) at the former McClellan Air Force Base for our field pilot test study because a stable 1,4-D and 1,2-dichloroethane (1,2-DCE) plume is present at low concentrations. The GW recirculation approach has been used to supply propane and oxygen into impacted GW to evaluate the degradation capability of the indigenous microbial population.



MW-10 1,4-D and 1,2-DCE conc. (2002-2013)



C_{in} = background 1,4-D concentration in GW
 C_{out} = 1,4-D concentration in injected GW
 C_r = 1,4-D concentration at the end of recirculation zone

Substrates and injection method

HD-10 BBQ propane gas tank

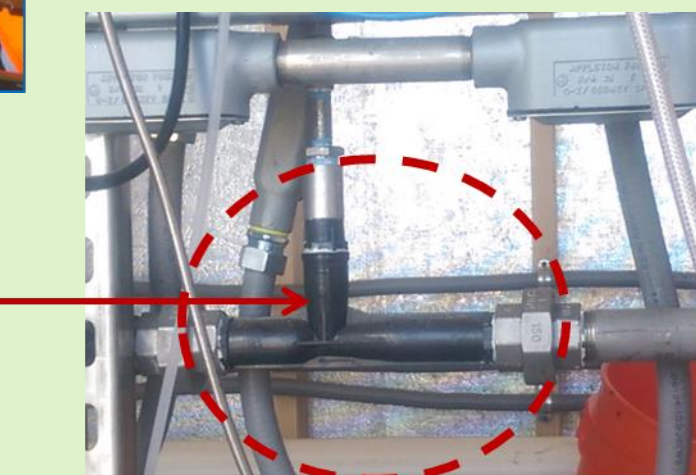
- propane (85-100%)
- butane & heavier (0-2.5%)
- ethane (0-5%)
- propylene (0-10%)



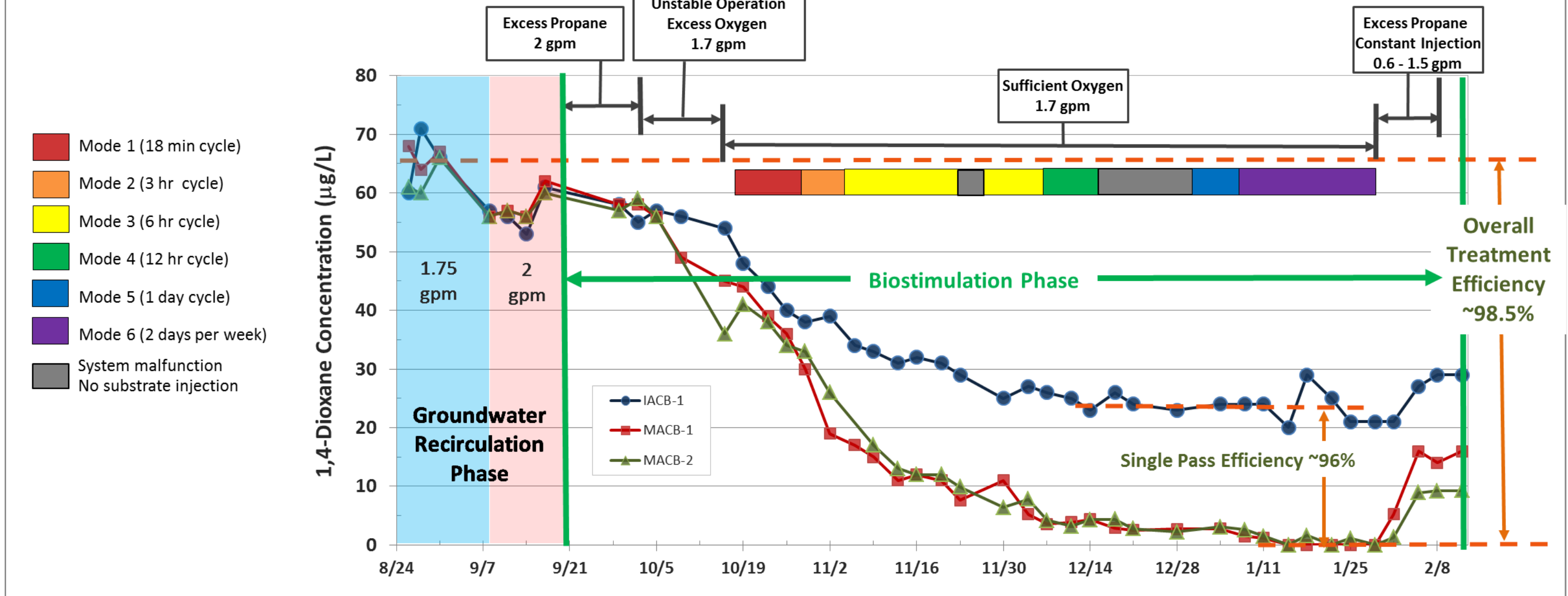
Gas flow controller

99% oxygen tank (industrial grade)

Venturi Injector



Biostimulation results



Single pass efficiency (η) = C_r / C_{out} (96%)
 Overall efficiency = C_r / C_{in} (98.5%)

$$\eta_{overall} = \frac{\eta}{1 - I(1 - \eta)}$$

Recirculation Ratio (Q_r / Q_{in})

The recirculation ratio is estimated to be 73%.

Treatment efficiency for co-contaminants

Chemical	C_{in} (ppb)	C_{out} (ppb)	C_r (ppb)	Single pass efficiency	Overall efficiency
1,2-DCE	11.7	2.9	< 0.18*	~ 97%	~ 99%
1,1-DCE	1.3	0.29 J	< 0.2*	~ 70%	~ 92%
TCE	3.9	1.8	0.23 J	~ 92%	~ 97%

* When C_r is below the method detection limit (MDL), 1/2 MDL is used for C_r .

Conclusions

- Some propane-oxidizing bacteria are not capable of degrading 1,4-D effectively.
- Aerobic cometabolic biodegradation can reliably decrease 1,4-D concentration in GW to below 3 µg/L and other co-contaminants to less than 0.5 µg/L
- The stimulated activity is robust because the degradation of 1,4-D and co-contaminants can last for more than a week without substrate injection.

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